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PROCEEDINGS

Larch genetics and breeding

Research findings and ecological-silvicultural demands

IUFRO WORKING PARTY S2.02-07
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Edited by

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Förteckning över utgivna **RAPPORTER** från och med 1982:
List of REPORTS from 1982 onwards:

1982

7. **Olsson, H.:** Skogsodlingsresultat i övre Norrland. Beskrivning och analys av 24 skogsodlingsobjekt. (*Results of artificial regeneration in northern Sweden. Description and analysis of 24 regeneration areas*).

1983

8. **Näslund, B-Å.:** Tallsådders utveckling fram till första gallring. Resultat från tre försöksytor med och utan enkelställning. (*Development of Scots pine seeded plantations to first thinning. Results from three experimental plots with and without release-cutting*).

9. **Björkroth, G.:** Inverkan av hyggesavfall på kvävet och den organiska substansen i några 14-18 år gamla försöksplanteringar med gran. (*The influence from slash on nitrogen and organic matter in some 14-18 years old experiments with Norway spruce*).

10. **Martinsson, O., Karlman, M. & Lundh, J-E.:** Avgångar och skador i odlingsförsök av tall och contortatall 4-9 år efter plantering. (*Mortality and damage in semipractical trials of Scots pine and Lodgepole pine 4-9 years after plantations*).

11. **Pehap, A.:** A review of literature in the subject of some physiologically active substances in the seeds and pollen of forest, fruit and agricultural species. (*En litteraturöversikt om några fysiologiska aktiva substanser i pollen och frön från upptagna arter*).

12. **Simak, M. & Sahlén, K.:** Bibliography on x-radiography in seed research and testing.

1985

13. **Bergsten, U.:** A study on the influence of seed predators at direct seeding of *Pinus sylvestris* L.

14. **Hägglund, B. & Peterson, G. (Editors).:** Broadleaves in Boreal Silviculture - an obstacle or an asset? (The report contains seventeen papers presented at the Kempe-symposium at the Swedish University of Agricultural Sciences, Umeå, in June 1984).

15. **Martinsson, O.:** Markberedningens inlytande på överlevnad, tillväxt och rot-skottrelation i föryngringar av tall, gran och contorta. (*The influence of site preparation on survival, growth and root/shoots ratio in young stands of Scots pine, Norway spruce and lodgepole pine*).

16. **Ekö, P-M.:** En produktionsmodell för skog i Sverige, baserad på bestånd från riksskogstaxeringens provytor. (*A growth simulator for Swedish forests, based on data from the National Forest Survey*).

17. **Pehap, A. & Sahlén, K.:** A literature review of seed respiration.

1986

18. **Näslund, B.-Å.:** Simulering av skador och avgång i ungskog och deras betydelse för beståndsutvecklingen. (*Simulation of damage and mortality in young stands and associated stand development effects*).

19. **Albrektson, A., Frivold, H., Holstener-Jörgensen, H., & Mälkönen, E.:** Published and Unpublished Biomass Studies in the Nordic Countries. An annotated bibliography up to 1982.

20. **Simak, M.:** Chromosome aberrations in stored seeds of *Pinus silvestris* and *Picea abies* and the consequences on plant properties.

1987

21. **Pehap, A., Henriksson, G. & Sahlén, K.:** Respiration of individual, germiating spruce seeds: Some investigations and measurements with the Warburg Direct Method.

Preface

The genus *Larix* Mill. (larch) represents a great part of the boreal and alpine forests. Larch species are the most common conifers in Siberia and they have an important role in European and North American forest ecosystems and forest economies. The value of these group of species are expected to increase in the future. There are at least three different reasons for that assumption: 1. Larch has highly appreciated technical wood properties. 2. Intensive cutting during the past three centuries, has made larch a threatened group of species in some parts of the world. 3. Increasing access to Siberia will make forestry and forest harvest of larch an important part of the forest economy and ecology.

In August 1995 a group of forest scientists gathered under the framework of IUFRO working group S2.02-07 in southern Sweden for exchange of experience in the fields of breeding and silviculture of larch. This proceedings was compiled on the basis of the presentations of this working group. I want to express my gratitude to everybody who contributed in one way or another.

Owe Martinsson

DISCLAIMER

Contents

Session I

Session II

Session III

Summaries of posters

Summary of field excursion

INTRODUCTION

"Spruce, pine, juniper and larch are superabundant in the forests of the North and grow so high that they may be compared to high towers". In this quotation larch in Sweden was first mentioned and illustrated in the "History of the Nordic people" published in Rome in 1555 by OLAUS MAGNUS (Fig. 1, quoted by SCHOTTE 1917). There are admittedly doubts as to whether the tree depicted as a larch is not in actual fact a yew.

Fig. 1: Drawing of spruce, pine, larch (top, from left) and juniper (bottom) from Swedish forests after OLAUS MAGNUS 1555 (from SCHOTTE 1917)

Be that as it may, larch is mentioned increasingly in Swedish literature already in the 17th and 18th centuries. In 1782, for example, ALSTRÖMER recommends the cultivation of "the larch tree and silver pine ... which grow quicker than any other tree known to me, and can be used both as building material and fuel and also for the promotion of beauty and peace" (quoted from SCHOTTE 1917).

Although it was not orginally indigenous to Sweden larch has evidently played a significant role since the second half of the 18th century in the country's forestry, which is by nature poor in species. It is undoubtedly thanks to Gunnar SCHOTTE that important findings became known at an early stage and in a comprehensive form on the site requirements, silvicultural behaviour and yield potential of this tree genus in Sweden. In his standard work which resembles a monography and was published in 1917 "Lärken och dess betydelse för svensk skogshushållning" (The Larch and its Importance in Swedish Forest Economy) he describes results of the cultivation of different larch species in his country. For the assessment 66 trial plots were already available under the care of the 'Swedish State Institute of Experimental Forestry'.

Besides the earlier larch cultures there are in Sweden numerous thorough younger trials of which reports have been given by, among others, KIELLANDER (1958), SIMAK (1979) and MARTINSSON (1992). Of particular interest here are the findings and experience gained by our Swedish colleagues in comparative trials of European and Japanese larch with Siberian and American larch species.

This year's meeting of our IUFRO Working Party in Sweden therefore promises to be attractive for all participants. In making the preparations care was taken to allow easy participation in the subsequent IUFRO World Congress in Finland (06-12 August in Tampere).

The theme of our meeting is "Larch genetics and breeding; research findings and ecological-silvicultural demands". The title is a challenge to assess larch research findings in the light of current requirements of an ecologically orientated silviculture. Contributions and discussion on this subject are possible on a broad basis so that all those interested in the subject matter can participate.

In arranging the programme we, together with the organizers, were guided by positive experience at earlier meetings of the Working Party. The lecture and poster programme has been spread over several days and is in each case combined with excursions to sightworthy larch stands and field trials.

The proposed lectures are divided into three main fields. Compared with previous meetings of the Working Party it is noticeable that for the first time reports are also given in striking intensity on important larch species which are indigenous in Russia and China. The ecological-silvicultural and economic importance of these species for the extended area of Asia can certainly not be questioned (Fig. 2). I am convinced that the contributions from eastern countries can moreover provide new important impulses for the Working Party's future orientation.

The burden of preparing this meeting lay this time mainly on our Swedish colleagues. In the name of IUFRO I give you hearty thanks for all your hard work. My thanks are due particularly to the host institution, the Swedish University of Agricultural Sciences in Umeå, and to Dr. Owe MARTINSSON who is responsible for the organisation. Finally I should like to thank all those who contribute to the success of this event by chairmanship, lectures, poster presentation, the conduction of excursions and participation in discussions.

I hope that new knowledge and shared experience will give a stimulus to our daily work after our return and let us remember with pleasure our stay in the beautiful country of Sweden.

Horst Weisgerber
Chairman

Hann. Münden, Germany
May 1, 1995

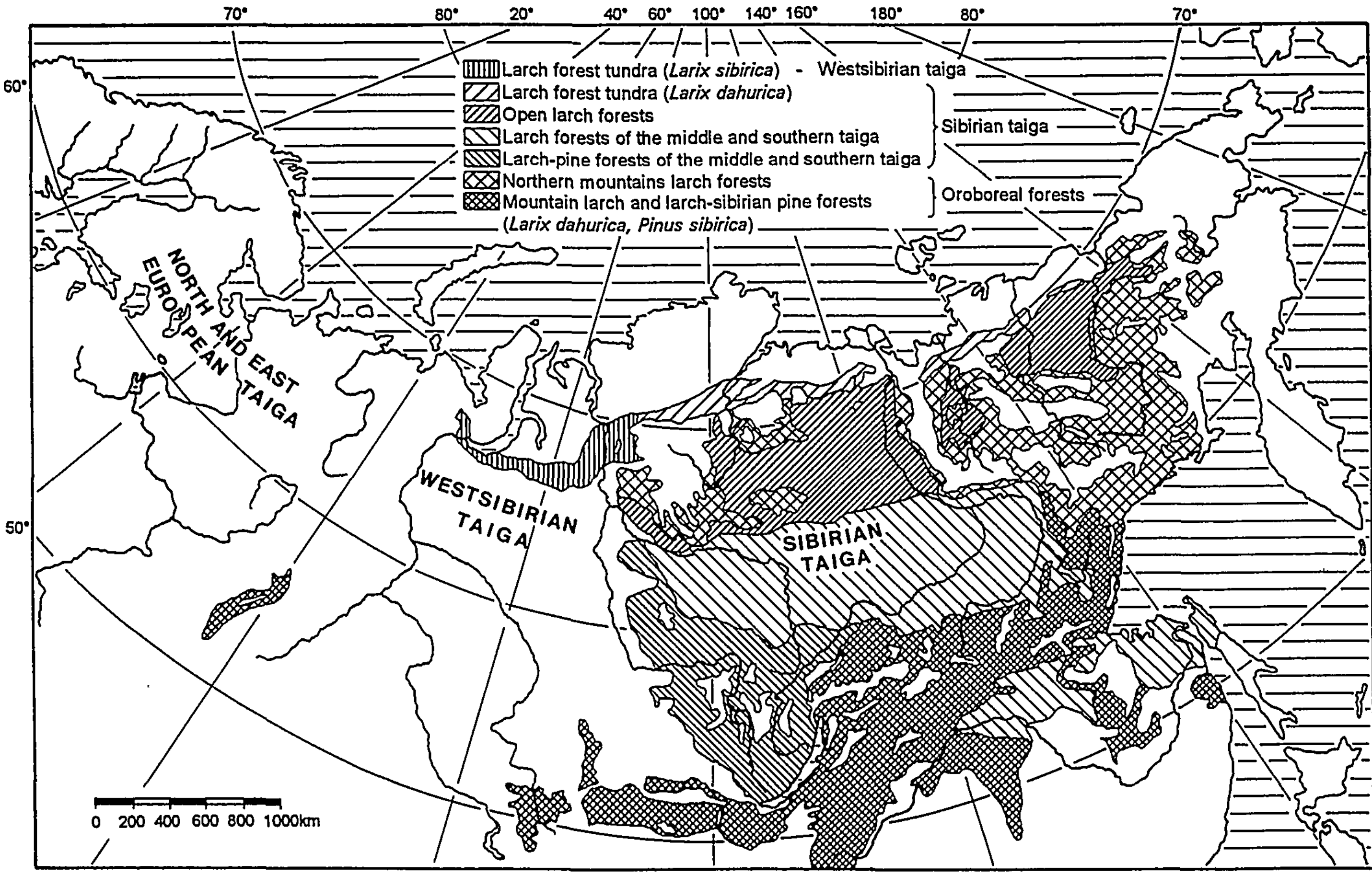

Fig. 2: Natural distribution and vegetation-geographical assignment of larch forests in Asia (from TRETER 1993)

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PROVENANCE TRIALS OF LARCH IN SIBERIA

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SUMMARY

Some results of provenance trials of larch in Siberia are given. These provenance trials were established in last thirty years by efforts of V.N. Sukaczev Institute of Forest. Provenances and species of larch were tested in some field trials distributed over Siberia between Lat. N 52° and 66°, Long. E 88°and 113°: near Krasnoyarsk, in Republic Khakasia (an altitudes of 800 and 1200 metres), in the Lower Yenisei near Turukhansk, in the west and south regions of Krasnoyarsk territory, in the Upper Lena, near Chita.

Larch species are wide distributed forestforming species of Siberia, but larch provenance trials began to be realized in this region only about 30 years ago. The earliest plantations of larch provenances were established firstly in some regions of Siberia in the 1964-1966.

Larch provenances trials in Transbaikal region (forestry Petrovsk-Zabaikalski) near east border area of *L. sibirica* were disturbed because of bad protection. They lost scientific value now. Two-year observations (Milyutin, 1967) showed that several provenances from Transbaikal region had superior survival. All provenances from Yakutia and the north regions of Yenisei basin, some provenances from Altai died in the first year. Several provenances from south regions of Siberia kept to the end of the second year.

Trials were more successful in 3 another experimental plots in Krasnoyarsk forest-steppe (experimental base of Institute of Forest "Pogorelski bor" to the west of Krasnoyarsk), in Uzhur forest-steppe (forestry Uzhurski in Krasnoyarsk territory), and in the West Sayan foothills (forestry Yermakovski in Krasnoyarsk terrotory). 10-12-year observations of 140 provenances of 6 species: *Larix sibirica Ldb., Larix sukaczewii Dyl., L. gmelinii (Rupr.) Rupr., L. x czekanowskii Sz., L. cajanderi Mayr, L. leptolepis (Siebold et Zucc.)* Gord. (the latest observations didnot confirm the belonging of these provenances to *L. leptolepis* have been summarized by A.I. Iroshnikov (1977). The largest differentiation was found for species with vast areas and great diversity of environmental conditions: *L. sibirica* and *L. gmelinii*. The stability and growth of introduced larch populations has decreased proportionally to increase of differences between conditions of experimental plots and origin of provenances. Such regularity shows first of all in the total elimination of the north populations of *L. sibirica, L. gmelinii, L. cajanderi* and alpine populations of *L. sibirica* from South Siberia.

Provenances of *L. sibirica* from low-mountain zone of Sayan and Kuznetski Ala-Tau, also from before Sayan region and Chulym-Yenisei interstream area (superior region for growth of *L. sibirica*) have the best parameters of growth and stability.

Bad growth and stability have been observed for *L. sibirica* from the middle-mountain zone of South Siberia, aslo from the middle taiga forests of West Siberia.

Provenances of *L. gmelinii* from the most of South-East Transbaikal regions and the Upper Amur regions grow better in first 5-8 years, than *L. sibirica* from its optimal zone. However, many provenances of *L. gmelinii* lose advantage in growth at the age 10-12 in connection with decreasing of increments and annual damages by frosts.

The next series of larch provenance trials was established in 1978-1981. Provenances were tested in Khakasia (forestry Oktyabrski) in mountain forest-steppe in 2 experimental plots: low-mountain (800 m above sea-level) and middle-mountain (1200 m above sea-level). Nine provenances of *L. sibirica*, eight provenances of *L. sukaczewii*, five provenances of *L. gmelinii* per one provenance for *L. x czekanowskii, L.cajanderi* and *L. leptolepis* have been tested.

During the first 5 years provenances of *L. sibirica* from Alpine Altai, *L. cajanderi* from Magadan district, *L. leptolepis* from Sakhalin died.

The native larch had not an advantage of growth in low-mountain zone in the first years (at the age of 5). It left behind the other provenances in height growth only at the age of 10 but some of them (*L. sibirica* from Buryatia, *L. sukaczewii* from Bashkiria and Sverdlovsk district) yielded to the native provenance little (8-20 cm).

Bad height growth in the first years is characteristic of almost all provenances in middle-mountain zone of Khakasia (annual increments are 8-31 cm). Apparently the specific conditions of middle mountain zone level considerable by differences in growth of investigated provenances. Some provenances of *L. sibirica* from Khakasia and Krasnoyarsk territory and *L. sukaczewii* from Sverdlovsk district were characterized with relatively good height growth at the age of 10.

Forestry Turukhansk (66°NL) placed near north border of middle-taiga forests was the most north experimental plot. Plantation was established in spring 1981 by five-year seedlings. Six provenances of *L. sibirica*, two provenances of *L. sukaczewii* and per one provenance for *L. x czekanowskii, L. gmelinii* and *L. cajanderi* have been tested here.

L. sukaczewii from the Middle Ural, as well as *L. gmelinii* from the Eastern Transbaikal region and *L. cajanderi* from coastal regions of the Okhotsk Sea had superior survival (45-52%) at the age 10 (autumn 1985). *L. sibirica* from Khakasia and the south regions of Krasnoyarsk territory had the most bad survival (6-10%).

Almost all provenances died at the age 17. Only 5 trees of *L. x czekanowskii* from the West Transbaikal region, 5 trees of *L. gmelinii* from the East Transbaikal region, 12 trees of *L. cajanderi* from the coastal region of the Okhotsk Sea were kept. All these provenances were characterized by very bad growth. *L. x czekanowskii* had at the age 17 the mean height in 174 cm. *L. gmelinii* - 145 cm, *L. cajanderi* - 186 cm. This trial showed the obvious perspectiveless of introduction of larch south provenances to the north regions.

Tests were not very successful in south-taiga forests of the Upper Lena basin (forestry Kachugski in Irkutsk district). Out of 3 plantations (1975, 1977 and 1979) only plantation of 1977 was relatively successful. Six provenances of *L. sibirica*, three provenances of *L. sukaczewii*, one provenance of *L. x czekanowskii* were sowed.

The analysis of these plantations was carried out only once at the age 4 (autumn 1980). It have been showed good survival of *L. sibirica* from Khakasia and *L. sukaczewii* from the Volga river region (Ivanovo district).

L. sukaczewii as well as some provenances of *L. sibirica* from Khakasia (forestry Oktyabrski) and south region of Krasnoyarsk territory were characterized by superior growth in the first years, in another experimental plots also. Bud growth was observed in some provenances from Khakasia and the Mountain Altai.

Differencies between good and bad growth of larch in this experimental plot only relatively, because, for example, superior provenances had the age 4 mean height only 30-32 cm and worse provenances - 12-19 cm.

Larch provenance trials in mountain-taiga forests of Eastern Transbaikal region (forestry Chitinski in Chita district) were began in 1979 and 1981. It is the only experimental plot of larch provenances trial in within the areas of *L. gmelinii*. Nine provenances of *L. sibirica*, per four provenances for *L. sukaczewii* and *L. gmelinii*, per one provenance for *L. x czekanowskii*, and *L. cajanderi* were planted.

Analysis of provenance survival showed that *L. sukaczewii* from the Volga river region as well as *L. sibirica* from the Mountain Altai died in this plot at the 9-11 years age. *L. cajanderi* from the Okhotsk Sea region died in the following years.

Observations of the provenances growth showed, *L. gmelinii* and *L. sukaczewii* were characterized equally good growth in the first 6 years. However *L. gmelinii* provenances showed superior growth already at the age 11. They were differ by stable annual increment in height (60-110 cm). *L. sukaczewii* were in growth behind *L. gmelinii* at this age considerably.

The last larch provenance trial was began in south-taiga plain forests of west regions of Krasnoyarsk territory. Eight provenances of *L. sibirica*, including four from Mongolia, five provenances of *L. sukaczewii*, per one provenance for *L. gmelinii* (from Mongolia) and *L. cajanderi* were planted in spring 1987.

This larch provenance trial differs from others. It was established in West Siberia firstly. In addition, larch provenance from Mongolia were tested in Russia firstly.

Provenances were analyzed in autumn 1994 at the age 11. It is necessary to note that *L. gmelinii* from the north-east Mongolia was eliminated practically already in nursery garden and only 3 plants kept at the age 11. The survival of *L. sibirica* ranged from 41 % (some provenances of Khakasia and Mongolia) to 80% (the native provenance). Provenances of *L. sukaczewii* as well as *L. cajanderi* from Magadan district had satisfactory survival (57-75%).

L. sukaczewii shows the superior growth in the first years in another experimental plots in Siberia also. *L. sukaczewii* from the Volga river region has at the age 11 the most height (470 cm). The provenances from Ural differs by good growth (306-383 cm). All provenances of *L. sibirica*, but one provenance from south regions of Krasnoyarsk territory, grow in the first years slower considerably. Even the native provenance has the mean height 252 cm. *L. sibirica* from Kkakasia and the Transbaikal region has approximately the same height (252-266 cm). 3 provenances from the East Chentei (Mongolia) show equally bad growth (190-198 cm) and one provenance grows even more worse (163 cm).

Three survived *L. gmelinii* trees from Mongolia are characterized by very bad growth (153 cm). One provenance of *L. cajanderi* (Magadan district) has mean position of the height at the age 11 (236 cm).

Trees of many provenances are damaged by bud gall midge (*Dasynerea rozhkovi*). Different rots are noticed also.

The analysis of studied larch provenance trials gives the scientific base for yield and transference of seeds of the most important Siberian forestforming species.

CONCLUSION

Provenances of *Larix sibirica* (55 provenances), *L. gmelinii* (29), *L. sukaczewii* (12) were tested mainly. *L. cajanderi* (5), *L. leptolepis* (4) and *L. x czekanowskii* (2) were studied less. The native provenances show best growth and survival in most cases, but some provenances from other regions were superior in height growth often in the first years. A few provenances of *L. sukaczewii* showed for example very good increment of tree height.

The provenances *L. cajanderi* from north-eastern regions of Siberia (Yakutia, Magadan district) and *L. sibirica* from high altitude sites of Altai showed very bad growth and survival. They were eliminated mostly in the first years. Trees of many provenances are damaged with bud gall midge (*Dasyneura rozhkovi*).

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THE LARCHES OF SIBERIAN PERMAFROST ZONE AND THEIR SPECIES PECULIARITIES IN PROGRESSIVE SUCCESSIONS

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SUMMARY

Some results of natural larch species investigations in permafrost zone of Siberia are given. Fructification regularities of each larch species and their peculiarities in postfire progressive successions are consided.

Siberia is the biggest forest region of Russia. It extends over 7 thousand kms from the West to the East and about 3 thousand kms from the North to the South.

Geographical location of this region in middle and high latitudes of the northern hemisphere determines its natural peculiarities. The climate of the most Siberian area is sharply continental. Average annual temperatures are below zero almost everywhere and in the north they are -16-18° C. The sum of active temperatures changes from 400-800°C in the north to 2200°C in the south. Accordingly vegetative period varies from 40-70 to 120-140 days. Annual precipitation is about 200-900 mm and it decreases from the west to the east regularly, 60-80 percent of annual precipitation falls on warm year season. Geographical regularities in spatial differentiation of forest cover are determined in Siberia not only by latitudinal zonality, but by vertical zones in mountains of the South and North East.

The main consequence of continental climate of Siberia is the forming of permafrost. It occupies about 40 percent of Siberian area and affects soil formation process, temperature and hydrological regime of the soils. The permafrost determines the peculiarities of formation, growth and forest community dynamics. In permafrost zone the depth of thawing out soil makes 20-200 cm in summer (Pozdnyakov, 1986).

Low temperatures are characteristic here for the active soil horizon. During summer they don't exceed more than +2+8°C in the 20 cm depth. We consider that fact is responsible for the substitution of usualin southern taiga forests light competition to the root competition in the northest boreal forests. It can be observed in progressive successions here. On a level with unfavourable temperature regime water tight frozen layers are the reason of soil overmoistening too. Frozen ground makes difficult plant growth especially in the first part of summer. That is why, open forests of low productivity are formed in the north.

The conifers prevail in Siberian forests. They make 87 percent of the area and 88 percent of growing stock (Sokolov and others, 1994). The forest structure is characterized by larch prevailing. Larch species are the main forest forming species of Siberia and make more than 40 percent of the total forest covered area.

Because of this reason the study of larch systematics and biology, formation and dynamic stand regularities is of great theoretical and practical value. But at present the Russian researchers have no common opinion about the number of larch species growing in Siberia.

N.V. Dylis (1947, 1961) considers three larch species are distributed on Siberian territory. They are *Larix sukaczewii Dylis, L. sibirica Ledeb.* and *L. dahurica Turcz. ex Traut.* The latter is divided by him into two geographical races - western and eastern.

E.G. Bobrov (1971, 1978) distinguishes three another larch species: *Larix sibirica Ledeb., L. gmelinii (Rupr.)* Rupr. and *L. cajanderi Mayr.* He does not declare *L. sukaczewii Dylis* as larch species.

L.I. Milyutin (1983) considers only two larch species in Siberia: *L. sibirica Ledeb.* and *L. gmelinii (Rupr.)* Rupr. and their hybrid complex - *Larix czekanowskii Sz.*

We share Bobrov's opinion and consider three larch species are growing in Siberia. They are *L. sibirica, L. gmelinii* and *L. cajanderi.* In their contact areas these species hybridize and form vast strips consisting of hybrid transitional populations with parent species features.

Without discussing the controversial questions of systematics we note in connection with permafrost distribution Larix gmelinii and L. cajanderi are the main and even the only forest forming species here. Larch forests from *Larix sibirica* with spruce, cedar (*Pinus siberica*) and birch are formed on long-term frozen soils in Western Siberia. The eastern area border of *Larix sibirica* concurs with permafrost distribution (Pozdnyakov, 1975).

Studing larch species have not only morphological distinctions, but are characterized by their own areas and a number of ecological peculiarities.

Larix gmelinii and *L. cajanderi* are the most adapted to permafrost existence. They can form the adventious roots when permafrost raises, are not too demanding from the soil fertility and the warmth. Due to these features mentioned larch species form the northern treeline and great massives of monodominant forests between Long. E 95-170°.

The main morphological difference of *Larix gmelinii* and *L. cajanderi* from another ones is an angle deflection size between the cone axis and the seed scales in mature cones. This sign is responsible for the sizes, shapes and mature cone structure. Besides that it is a great importance for silviculture because of its influence on the seedfall and its dates.

In natural populations of *Larix gmelinii* the total opening of seed scales do not happen. The seeds begin to disperse only in spring and summer of next year after seed one. According to our observations in the north of Middle Siberia from 5 to 15 percent of seeds are reserved in the cones for 3-4 years.

In *Larix cajanderi* populations the seedfall usually takes place during a week after their ripening, as a rule, at the end of August or in the beginning of September (Pozdnyakov, 1975).

The main number of *Larix siberica* and *L. czekanowskii* seeds is falling off in seed year, the rests - in next year spring.

Consequently, the seedfall and its dates for every Siberian larch species are rather specific. *Larix gmelinii* populations have their seed reserve constantly. On the contrary *Larix sibirica* and *L. cajanderi* have that one only in the seed years.

These circumstances predetermine the first stage of progressive successions under forest fire affecting especially. The latters are the main disturbing factors in northern forest ecosystems.

As a result of carried out investigations the main trends of postfire progressive successons in larch stands are outlined. They are:

1. the reforestation without species interchange:
   a) with excessive stand density;
   b) with heightened stand density;
   c) with optimal stand density;
   d) with insufficient stand density;
2. the reforestation with the interchange of larch forests afterfire sprout birch forests;
3. the reforestation with the interchange of larch formation by secondary shrub tundra;
4. the reforestation with the interchange of larch formation by sedge communities.

As usual, postfire reforestation in *Larix gmelinii* and *L. cajanderi* stands is going on successfully. Possible scenarious of postfire dynamic variations are determined by such leading factors as larch species, their habitats and microrelief peculiarities, fire kind and power, character of fructification. By other words, in each certain case dynamic processes of forest changes are the result of influence of some factors simultaneously. However, stable existence of larch forests depends on the rate of adapting to changing environmental conditions and on ability of optimal using of ecological niche.

The ground fires prevail in permafrost, zone absolutely. They cause the organic matter mineralization and the thermal amelioration of frozen soils. But even after fire influence undamaged trees are reserved on the microfalls and linear depressions of the surface. Some trees with fire damaged shallow rootage keep their vital activity for 3 or 4 years and continue to fructify annually.

When marginal seeding of postfire areas is abundant fire-borned larch forests with excessive and heightened stand density are formed here. On the first reforestation stages their density varies from some thousand to 1,5 billion trees per 1 hectare. On the next stages of progressive successions the stand density in comparison with the initial one is changed very slowly. It seems that these forests stop their growth. In Russia they are called "eternal polewoods".

When marginal seeding of postfire areas is optimal the typical uneven-aged larch stands are formed. Their stand density varies within 250-700 trees per 1 hectare. Such forest communities dominate throughout the Siberian north vegetation.

If marginal seeding of postfire areas is insufficient the destroyed larch stands are followed by fire-borned larch sparse communities. This is characteristic of *Larix cajanderi* populations when larch stands are destroyed absolutely. The same scenarious takes place in *L. gmelinii* populations when about three years of bad seed harvest are followed by catastrophic fire. In that case the final stands can calculate only a few or 40-70 larch trees per 1 hectare.

The reforestation with species interchange are characteristic of *Larix gmelinii* stands. The larch or mixed larch-spruce-birch stands are followed by postfire sprout birch forests. The latters are usually replaced by initial larch forests only in 50-80 years.

The secondary shrub tundra communities raises on the burns where the larch stands are destroyed absolutely by running catastrophic fires. In such habitats shrub species begin to propagate by natural layering. Thus, larch trees are supplanting shrubs. Further larch reforestation proceeds for decades.

Sedge communities appear after independent ground fire influence in the habitats with fossil ice. The larch stand destruction leads to the thermokarst. The thermokarst lakes surrounded by sedge communities are formed here. The progressive successions proceeds for decades, even sometimes hundreds years.

CONCLUSION

Thus, data of carried out investigations show three larch species are growing in Siberian permafrost zone. They are *Larix sibirica, L. gmelinii* and *L. cajanderi*. In their contact areas these species hybridize and form transitional populations.

Biological and ecological features of every Siberian larch species are specific. These peculiarities become apparent in progressive successions. Postfire reforestation of *Larix gmelinii* stands is going on successfully without species interchange. In years of bad seed harvest *Larix cajanderi* stands are followed by fire-borned larch sparse forests and the secondary shrub tundra communities. Postfire reforestation of *Larix sibirica* leads to postfire sprout birch forests.

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POPULATION STRUCTURE OF LARCH FORESTS IN THE URALS

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SUMMARY

The variability and population structure of larch (*Larix sukaczewii* Dyl.) naturally growing in the Urals was studied on the basis of biometric analysis of generative organs. The obtained results point to the existence of 11 phenotypically different local populations of *Larix sukaczewii* in the Urals. Four populations are identified in the South Urals: Marginal, central, high-mountainous south-uralian and Bashkircis-uralian. Middle-uralian, Perm cis-uralian, central north-uralian and high-mountainous north-uralian populations are determined in the Middle and the North Urals. Three populations of *Larix sukaczewii* are identified in the Sub-Polar and the Polar Urals: Subpolar-uralian, Pechora-Thiman cis-uralian and polar-uralian.

Keywords: *Larix sukaczewii*, morphological traits, population structure, phenotypic variability, introgressive hybridization.

INTRODUCTION

Larix sukaczewii is characterized by high forestry and silvicultural importance. The area of this species in the Urals was significantly reduced during the last centuries (Dylis, 1947).

Taxonomically valuable morphological traits of generative organs are often used for the study of intraspecific differentiation and introgressive hybridization in conifers. Some aspects of phenotypic variability of Larix sukaczewii were studied in the Urals earlier (Dylis, 1947; Pugach, 1964; Putenikhin, Starova, 1991).

In the given research work population structure and variability of *Larix sukaczewii* on the whole territory of the Urals including Cis- and Trans-Urals are investigated on the basis of phenotypic analysis.

MATERIAL AND METHODS

A four-level hierarchical system of samples was realized: Natural-historic larch locations, sample plots within locations, trees in sample plots, generative organs from each tree. Twentytwo larch locations were used; two of them were in the adjacent part of *Larix sibirica* range in West Siberia. Sample plots in each of these locations (from 1 to 5 per location, 66 in total) were established and cone material was collected. 13 quantitative and 9 qualitative traits of generative organs were characterized: parameters of cones, seed scales and seeds (including relative traits), form of the upper edge and configuration of plane of seed scale, size of bracts, pubescence, density and color of mature seed scale and others (Dylis, 1947; Kruklis & Milyutin, 1977). Different multivariate methods were used for treatment of initial material.

RESULTS AND DISCUSSION

Mahalanobis distances by a complex of quantitative traits (Miller & Kahn, 1965) and similarity values by a complex of qualitative traits (Zhivotovsky, 1991) were calculated. In general, Mahalanobis distance (D) is varied from 0 (full similarity of samples) to infinity; similarity value (SV) is varied from 0 (full dissimilarity) to 1 (full similarity).

The absence of reliable statistical differences by Mahalanobis distance between sample plots within each location except several sample plots was found (average D=1.012). The similar picture was revealed after comparison of sample plots within locations using similarity value (average SV=0.9972).

Several statistically distinct groups of locations which can be determined as phenotypically different local populations were identified in the Urals on the basis of these two methods. Average Mahalanobis distance between locations within populations is 1.359. Mahalanobis distances between populations changed from 1.596 to 5.435 (average D=3.287). Average value of similarity of locations within populations is 0.9954. Value of similarity of populations varies from 0.8475 to 0.9948 (average SV=0.9511).

In the South Urals four populations are singled out. Marginal south-uralian population is situated at the southern forest-steppe limit of *Larix sukaczewii* distribution in the Urals. Central south-uralian population is represented by larch forests in the middle-mountain part of the South Urals and Trans-Urals. High-mountainous south-uralian population includes larch stands on high-elevated ridges over 800 m above sea level. Bashkir cis-uralian population is characterized by small isolated larch sites within the dark-coniferous taiga of Ufa plateau.

Four populations are determined in the Middle and the North Urals. Middle-uralian population is represented by stands on not high mountains in the Middle Urals and the northern part of the South Urals. Central north-uralian population inhabits the northern part of the Middle Urals, slopes of the north-uralian mountains as well as uplands in Sverdlovsk and Tyumen Trans-Urals. Perm cis-uralian population is situated along the rivers Kama and Vishera to the west from the Urals. High-mountain north-uralian population is near the upper timber line on high ridges.

Further to the north three separate populations were found: Subpolar population in the central part and at the western and eastern macroslopes of the Sub-Polar Urals, Pechora-Thiman cis-uralian population in the South Thiman ridge and along the Pechora river, polar-uralian population.

Populations in the South Urals are relatively close to each other by quantitative traits (average D=1.837) and they differ more by qualitative characteristics (average SV=0.9796). In the Middle and the North Urals, on the contrary, populations differ more from each other by parameters of generative organs (average D=2.753) but are relatively similar by qualitative traits (average SV=0.9869).

Sub-polar, Pechora-Thiman and polar-uralian populations have significant differences both from each other (average D=2.231; average SV=0.9443) and especially from the rest of populations (average D=3.619; average SV=0.9244). Sample plots of *Larix sibirica* are at a great statistical distance from *Larix sukaczewii* populations.

Generalized estimations of intrapopulational diversity are given in Table 1. It demonstrates gradual increase of the variability level in direction from the South to the Polar Urals.

For example, in south-uralian populations we practically do not meet trees with long bracts of cones, leathery, brown-violet seed scales with recurved outside upper edge. In the Middle and the North Urals these forms begin to appear in populations, and in the Sub-Polar and the Polar Urals they constitute a significant part of stands.

Table 1. Intrapopulational phenotypic variability of Larix sukaczewii in the Urals

Population	C.V. (%)	M	Population	C.V. (%)	M	Population	C.V. (%)	M
1-MS	5.771	2.351	5-MU	8.167	2.526	9-SP	9.471	3.151
2-CS	6.392	2.384	6-PC	8.317	2.651	10-PT	8.248	2.641
3-HS	6.720	2.565	7-CN	7.996	2.615	11-PU	8.893	3.260
4-BC	5.413	2.190	8-HN	9.077	2.817			

Notes: 1) 1-MS - marginal south-uralian population, 2-CS - central south-uralian, 3-HS - high-mountain south-uralian, 4-BC - Bashkir cis-uralian, 5-MU - middle-uralian, 6-PC - Perm cis-uralian, 7-CN - central north-uralian, 9-SP - sub-polar, 10-PT - Pechora-Thiman, 11-PU - polar-uralian;

2) C.V. - generalized coefficient of variation of quantitative traits, M - conventional value of intrapopulational diversity by a complex of qualitative traits (Zhivotovsky, 1991).

The increase of variability in this direction may be connected with larger sizes of populations in the northern part of the *Larix sukaczewii* range in the Urals, certain adaptivity of larch forests under these conditions, the process of introgressive hybridization with Larix sibirica.

We carried out the preliminary analysis of introgressive hybridization in some populations using hybrid index method (Andersson, 1949) (Table 2). The results show high frequency of hybrids in polar regions and are in conformity with Dylis (1947).

Table 2. Form composition of larch populations in the Urals

Population	Percentage of trees (%) of:		
	Typical forms of Larix sukaczewii	Intremediate forms	Typical forms of Larix sibirica
2-CS	99.6	0.4	0
5-MU	96.7	3.3	0
7-CN	98.6	1.4	0
9-SP	69.2	30.0	0.8
11-PU	46.7	51.1	2.2

Significant participation of intermediate forms is also revealed in *Larix sibirica* eastwards the Ob river. Similar results were also found in *Larix sibirica* for the whole forest-tundra subzone in West Siberia (Matveyev, 1995). Now, we really may transfer the boundary of this zone to the Trans-Ob region in West Siberia.

Clearly expressed phenotypic differentiation of *Larix sukaczewii* into several populations in the Urals is probably connected with the complex processes of movement and evolutionary development of ancient *Larix sukaczewii* populations (Putenikhin, Starova, 1991). In the South, the Middle and the North Urals such differentiation may be explained by the interrelations with other conifer and broad-leaved tree species and significant change of natural climatic conditions within the region during Holocene.

The main basis for the formation of sub-polar and polar populations was obviously advancement of *Larix sukaczewii* to severe natural regions on the one hand, and the process of introgressive hybridization with Larix sibirica on the other hand.

Thus, *Larix sukaczewii* in the Urals is found to be differentiated into several phenotypically different local populations.

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INTRASPECIFIC VARIABILITY OF EUROPEAN LARCH FOR WOOD PROPERTIES : PRELIMINARY RESULTS

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SUMMARY

Wood properties of several natural populations of European larch (Larix decidua Mill.) were determined from samples collected in one replicate of the II. International IUFRO provenance experiment, planted in Brittany in 1959.

According to provenances, proportion of heartwood ranges from 35 to 58 % of basal area, basic density from 442 to 505 g/dm^3 and Young modulus of elasticity from 8474 to 14522 MPa. Positive correlations between girth and heartwood proportion and between wood density and modulus of elasticity but negative correlations between ring width and both density and MOE have been found both at the individual and at the population levels.

Variability between and within provenances is high for two major traits (proportion of heartwood and Young modulus of elasticity) for which a SW - NE gradient is shown. For wood density parameters including pilodyn, a greater homogeneity is observed. Besides a now largely recognized superiority for growth traits, Central European populations from the Sudetan Mountains and Central Poland would also produce wood with better properties. On the reverse, Alpine populations from the French Alps growing at low elevations have a slower growth, a denser wood with less heartwood and less strength. Used as a control, the hybrid larch origin (Larix x eurolepis) represents the best compromise for wood properties with the highest strength but an average wood density and one of the highest proportion of heartwood.

These preliminary results must be confirmed from a larger set of provenances and completed with other major wood properties such as durability and shrinkage.

Keywords : European larch, variability, provenance, wood, density, modulus of elasticity, heartwood.

Table I. Description of provenances

Geographic zones and provenances	Country	provenances number	Latitude	Longitude	Elevation (m)	Mean annual rainfall (mm)	Mean temperature (°C) annual	May-September
European larch (<u>Larix decidua</u>)								
South-Western Alps								
Embrun Ristolas (Queyras)	F	22	44°47'N	6°57'E	1600	1050	6.1°	12.3°
Embrun Aiguilles (Queyras)	F	23	44°47'N	6°54'E	1560	1050	6.1°	12.3°
Briançon Montgenèvre (Briançonnais)	F	24	44°56'N	6°43'E	1730	808	-	-
Briançon Villard (Briançonnais)	F	26	44°52'N	6°39'E	1400	620	6.2°	13.1°
Southern Pre-Alps								
Cavalèse (Val di Fiemme)	I	16	46°19'N	11°27'E	1200	860	8.7°	16.8°
Cavedine (Val Sugana)	I	20	45°59'N	11°04'E	600-700	1190	11.0°	16.0°
Interior Alps								
Mühldorf (Tauern)	A	3	46°52'N	13°21'E	900	1100	7.0°	14.2°
Northern Alps								
Langau 38/41 (Voralpen)	A	7	47°49'N	15°10'E	1100	1780	3.9°	10.9°
South-Eastern Pre-Alps								
Wechselgebiet	A	11	47°30'N	16°02'E	1000	1028	6.1°	13.1°
Sudetan Mts								
Zabreh-Dubicko	CS	39	49°50'N	16°58'E	400	670	7.5°	15.1°
Ruda nad Moravou	CS	40	49°59'N	16°54'E	480	670	7.9°	15.7°
Olomouc	CS	106	49°36'N	17°16'E	-	-	-	-
Hradec nad Opavou	CS	107	-	-	400	-	-	-
Central Poland								
Grojec	PL	104	51°50'N	20°45'E	180	-	-	-
Non-autochtonous								
Neumünster (Schleswig)	D	34	54°15'N	10°10'E	50	720	8.0°	14.4°
Schlitz 65 (Hesse)	D	28	50°43'N	9°31'E	335	634	7.8°	14.2°
Dobris (Bohême)	CS	30	49°47'N	14°11'E	500	590	-	-
Japanese larch (<u>Larix kaempferi</u>)								
Ina (Hondo)	J	36	35°52'N	138°04'E	1200	1900	4.8°	-
Hybrid larch (<u>L.decidua</u> x <u>L.kaempferi</u>)								
Humlebaek[1] (Sjaelland)	DK	110	55°58'N	12°33'E	-	-	-	-

1) FP201DK seed orchard

INTRODUCTION

A broad variability between natural populations of European larch (Larix decidua Mill.) has been reported by numerous authors (see Schober, 1985 ; Weisgerber and Sindelar, 1992) for many traits : e.g. survival, phenology, growth, stem form, branching habits, canker resistance. Major results are issued from the two IUFRO International provenance experiments established by 1944 and 1957 thanks to Dr. Schober in Germany. Trials are now more than 35 years old and amazingly no (or at least no published) information on wood quality traits is actually available.

This paper takes advantage of a recent synthesis of all data collected in the French replicate of the II.International IUFRO provenance experiment (Pâques, 1994) to present some preliminary results on natural variability for wood properties.

MATERIAL AND METHODS

Plant material

The material used in this study is issued from the provenance experiment of Coat-an-Hay in Brittany (Longitude : 3°25'W ; Latitude : 48°31'N ; Elevation : 200 m). This trial is at the most western edge of the IUFRO network in typical oceanic conditions and is for that reason particularly original (Lacaze and Lemoine, 1965).

The trial was planted in 1959 according to a balanced incomplete randomized block design with 5 replications, 21 blocks and 5 plots/block of 11 x 11 plants planted at 2 x 2 m. Three thinnings were realized during winters 1973/74, 1980/81 and 1984/85 ; in order to homogenize the silvicultural treatments according to plot vigour, selective thinnings with space coefficients of Hart-Becking (after thinning) between 25 and 28 % were preferred to systematic thinnings. Unfortunately, a severe storm in October 1987 has heavily damaged the plantation and only 10 blocks out of 21 remained untouched.

In total, 14 populations representative of the natural area of European larch were used in this study and compared to three non-native populations of European larch, one provenance of Japanese larch and one F1-hybrid progeny between European and Japanese larches from a Danish hybridization orchard. Description of the material is given in Table I.

Sampling and Measurements

Besides a number of growth and stem form traits, the results of which are summarized in Pâques (1994), several wood quality parameters were measured before and after a fourth thinning during winter 1993/94.

A first set of measurements, realized at the end of 1991 before thinning on a random sample of 20 trees per population, includes :

1. pilodyn measurement (needle diameter : 2.5 mm ; 6 J) under bark at 1.3 m ;

2. average wood basic density estimated by Keylwerth's (1954) method from two opposite increment cores of 5.5 mm diameter collected at 1.3 m ;

3. the proportion on basal area of heartwood, estimated as $d^2/(a+d)^2$ from measurements on increment cores of heartwood (d) and softwood (a) radial lengths.

To control and avoid compression wood, two opposite measurements (North and South) were considered.

A second set of parameters were then obtained from fallen trees after the fourth thinning, at 36 years from seed. Out of each 80 cm-buttlog, a transverse board (5 cm thick) including the pith was sawn at perpendicular to the East-West direction so that a standardized 50 x 2 x 2 cm wood probe could be obtained. As a rule, the probe was sawn from the shortest side from the pith, at the most external edge of the heartwood and with a number of knots as small as possible. In total, 98 samples were analyzed. They represent 4 to 7 trees per provenance from a limited number of provenances.

Measurements include :

4. the average ring width, obtained by dividing the side length of the probe (2 cm) by the number of annual ring limits ;

5. wood density at 12 % humidity : estimated by the ratio of the weight of the wood probe on its volume calculated from length measurements. The value obtained at a given humidity (controlled at the two external sides of the probe) is then corrected to obtain density at 12 % humidity ; it represents density of the last rings of the heartwood ;

6. the Young modulus estimated by a resonance vibration method following Haines et al. (1993).

Statistical analysis

Due to the numerous factors which have naturally (mortality, destruction by the storm of 1987) or artificially reduced (4 thinnings) the initial number of trees per provenance, it was difficult to take advantage of the initial statistical experimental design.

Out of the 10 remaining blocks, 3 new blocks were re-designed in order to get a sufficient and balanced number of trees per provenance and per block.

The following statistical model was then used :

$$Y_{ijk} = \mu + b_i + p_j + \varepsilon_{ijk}$$

with b_i, p_j and ε_{ijk} : respectively the block effect, the provenance effect and the error term. Provenance means adjusted to block effects (fixed) are then presented and compared.

RESULTS

Average results at the individual tree level are presented in Table II. A broad phenotypic variability is observed for all traits, except for density parameters including indirect pilodyn measurements.

Table II. Average individual performances

Traits	Minimum	Mean	Maximum	CV (%)
1 st set of data (374 trees)				
BH. girth (cm)	25.0	72.3	135.0	24.9
Pilodyn (mm)	7.5	10.9	17.5	14.4
Basic density (g/dm^3)	369.0	480.0	581.6	7.5
Heartwood proportion (%)	10.5	50.8	87.6	22.6
2 nd set of data (98 trees)				
Ring width (mm)	1.4	3.4	6.6	29.8
Density at 12% (kg/m^3)	515.0	635.8	761.0	9.7
Young modulus (MPa)	3683.0	11930.0	19030.0	28.1

Comparison between European larch provenances

As shown in Table III, significant or highly significant differences between provenances are noticed for all traits, except for wood density at 12 % humidity.

Heartwood proportion

The average proportion of heartwood at age 34 reaches 50.3 % of basal area for European larch populations with a range between 34.9 % (Embrun Ristolas) and 58.1 % (Grojec). A clinal variation from the South-West to the North-East of the natural range is observed (Fig.1a) : the South-Western populations from the French Alps are characterized by the lowest values while provenances from the South-Eastern pre-Alps, the Sudetan Mountains and Central Poland have the highest proportion of heartwood. The non-native provenances of Schlitz and Neumünster are also characterized by high proportions of heartwood. As indicated by coefficients of variation, variability within provenances is also important.

Table III. Provenance performances : means adjusted to block effects (expressed in % of global means) and intra-provenance coefficients of variation (cv)

Provenance	BH.Girth		Pilodyn		Basic Density		Heartwood %		Young modulus	
	Mean	cv	Mean	cv	Mean	cv	Mean	cv	Mean	cv
S-W. Alps										
22	76.2	35.0	88.5	14.9	103.5	6.8	69.8	34.6	89.4	38.0
23	90.9	34.9	87.7	18.7	104.9	8.8	94.3	21.2	(86.0)	(23.3)
24	106.4	30.5	94.6	8.7	96.6	5.4	80.1	25.2	71.7	33.7
26	98.7	33.4	95.0	12.2	100.2	5.9	83.2	31.2	(72.4)	(50.5)
S. Pre-Alps										
16	99.8	21.2	91.2	16.0	104.0	5.5	100.6	14.8	-	-
20	107.7	22.5	112.6	7.7	102.1	7.3	98.5	18.7	(91.2)	(19.1)
Interior Alps										
3	106.0	20.1	89.2	10.6	103.5	4.9	103.5	18.2	(102.6)	(11.7)
N. Alps										
7	96.8	30.9	93.0	14.5	99.1	7.4	97.5	23.3	98.8	38.1
S-E. Pre-Alps										
11	103.6	12.3	112.0	8.8	102.0	7.2	108.9	12.1	107.4	22.6
Sudetan Mts										
39	93.6	21.4	97.9	15.0	100.3	7.6	97.3	25.7	111.3	26.9
40	111.3	22.1	115.2	14.3	95.0	8.5	107.7	24.9	122.9	12.7
106	96.2	28.8	109.8	13.9	96.1	7.9	105.2	21.3	(93.3)	(21.8)
107	105.0	24.0	102.0	16.7	91.6	7.8	99.2	18.2	103.8	10.2
Central Poland										
104	95.1	23.9	110.4	6.2	102.4	4.2	109.8	21.5	122.9	19.5
Non-autóchtonous										
28	88.6	32.3	95.8	21.3	98.3	5.9	110.2	24.1	-	-
30	93.6	22.7	88.7	12.9	104.5	5.6	101.0	18.5	(112.3)	(26.4)
34	110.5	17.4	119.1	7.7	96.1	5.7	104.2	16.3	-	-
Japanese larch										
36	98.3	9.2	97.6	13.3	99.1	6.2	113.6	18.2	111.2	16.9
F1-hybrid larch										
110	109.9	11.3	91.4	8.3	102.8	4.3	112.6	10.2	127.6	18.6
Mean- inter-provenances CV	72.9 (cm)	8.8	10.9 (mm)	10.2	479.7 (g/dm^3)	3.6	51.0 (%)	11.2	11490.8 (MPa)	15.8
F (df)	2.2^{**} (18, 342)		3.5^{***} (18, 342)		3.9^{***} (18, 342)		4.6^{***} (18, 342)		2.1^{*} (9, 51)	

*, **, *** = significant at $\alpha = 0.05$, 0.01 and 0.001 respectively / - data non available

Pilodyn and Wood density

The length of penetration of the pilodyn needle averages 10.9 mm and extends from 9.4 mm up to 12.9 mm.

Among all traits, average basic density has the lowest coefficients of variation both at the intra- and inter-provenances level. It averages 482.4 g/dm^3 with a range between 442.1 and 505.4 g/dm^3. The lowest value is recorded for provenance 107 (Hradec nad Opavou) and the highest for provenance 23 (Embrun Aiguilles).

As a whole, the Alpine populations from West to East are characterized by the highest values except for Langau ; on the opposite, the Sudetan provenances have the lowest basic density (Fig.1b). The wood of the Central Polish provenance is also among the densest. Among non-native provenances, the Sudetan provenance of Dobris has the second highest density while Schlitz and Neumünster are below average.

For density at 12 % humidity which concerns density at room humidity of the last rings of the heartwood, no significant differences between provenances are observed. Mean values (not presented) range from 582 up to 685 kg/m^3.

Young modulus of elasticity (MOE)

Mean provenance resonance vibration modulus of elasticity reaches 11490 MPa. The lowest value is recorded for provenance 24 (Briançon Montgenèvre) : 8474.5 MPa, and the highest for provenance 104 (Grojec) : 14522.5 MPa. Roughly speaking, MOE increases from West to East (Fig.1c) with the highest strength for Sudetan and Polish provenances. The non-native provenance of Dobris from the Sudetan Mountains has also a good strength.Variation within provenances seems to be high as indicated by the intra-provenance coefficients of variation.

Comparison between European, Japanese and hybrid larch

F1-hybrid larch was compared to both European and Japanese larch. The Sudetan provenance Hradec nad Opavou (107) was chosen to represent the European larch as it was one of the fastest growing provenances in the experiment (Pâques, 1994) ; Ina is used as the reference for Japanese larch. Results are summarized in Table IV.

Table IV. Relative superiority of F1-hybrid larch (prov.110) over European (prov.107) and Japanese (prov.36) larches

Species	BH.girth (cm)	Heartwood proportion (%)	Basic density (g/dm^3)	Density at 12 % (kg/m^3)	Young modulus (MPa)
Means	80.2	57.4	492.9	639.4	15073.6
Superiority over					
European	**104.7**	**113.7**	**112.2**	**102.8**	**122.9**
Japanese	**111.9**	**99.1**	**103.6**	**103.7**	**114.7**

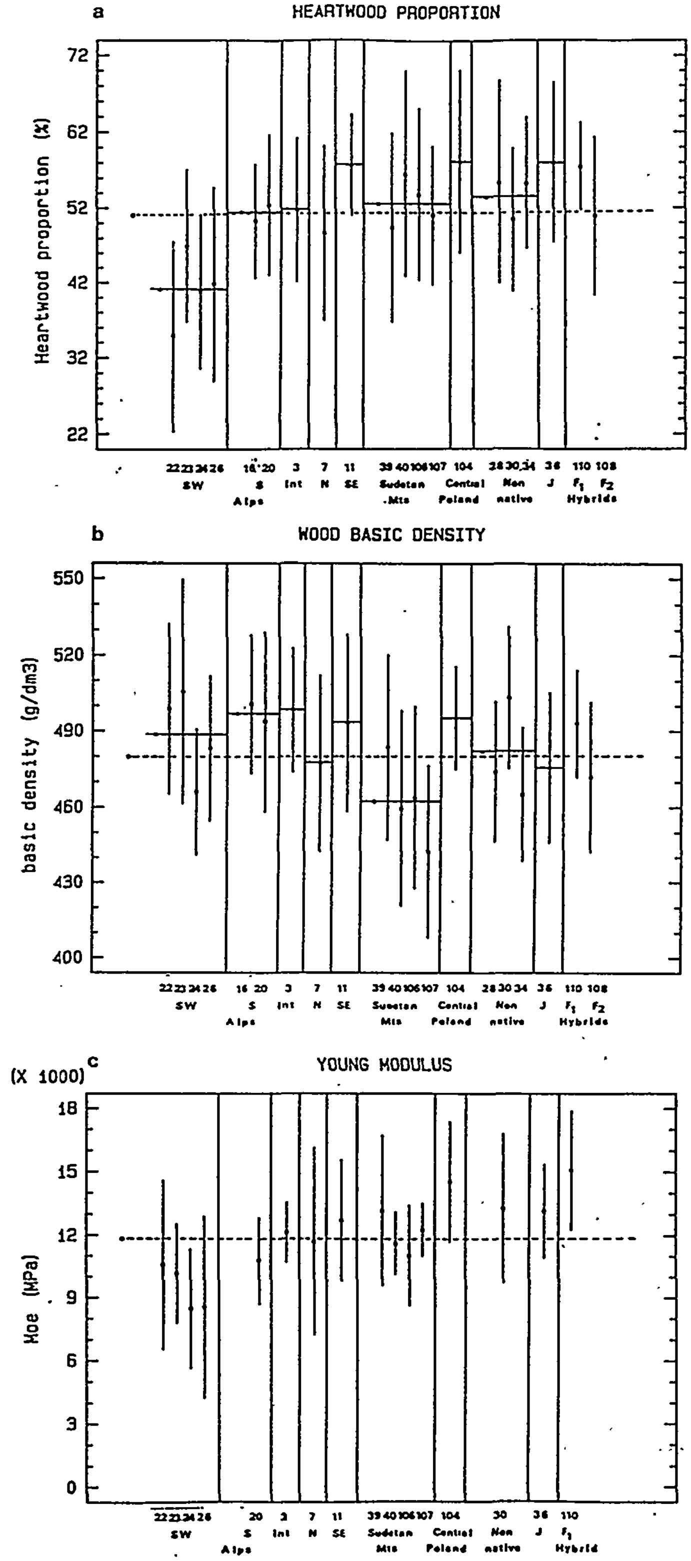

Fig. 1. a, b, c. Mean provenance performances (+/- 1 se) for (a) heartwood proportion , (b) wood basic density and (c) Young modulus of elasticity.

For all traits, hybrid larch appears superior or at least equivalent to both its parental controls. Superiority is usually much more important over the European Sudetan larch population, except for BH.girth. Hybrid larch is growing faster, has a higher proportion of heartwood, a more dense wood with a greater strength. Its wood has properties more similar to those of Ina, the Japanese larch.

Correlations between traits

Though significantly different from 0 (at α = 0.01 %), correlations between traits calculated at the individual level, are just moderate as shown in Table V.

Table V. Correlation coefficients (x 1000) between provenance adjusted means (above diagonal[1)]) and between individuals (*below diagonal*[2)])

1st sample

	BH.Girth	Pilodyn	Basic density	Heartwood %
BH.Girth	1000	473^{*}	-332^{ns}	491^{*}
Pilodyn	360^{***}	1000	-465^{*}	550^{*}
Basic density	-375^{***}	-558^{***}	1000	-140^{ns}
Heartwood %	456^{***}	305^{***}	-108^{ns}	1000

2nd sample

	Ring width	Density at 12%	Young modulus
Ring width	1000	-571^{ns}	-500^{ns}
Density (12%)	-570^{***}	1000	667^{*}
Young modulus	-560^{***}	720^{***}	1000

1) *, **, *** : significant at α = 0.05, 0.01, 0.001 ; df = 20, df = 10 respectively for the 1st and 2nd samples

2) **, **, *** : significant at α = 0.05, 0.01, 0.001 ; df = 374, df = 63 respectively for the 1st and 2nd samples*

Diameter growth traits (BH.diameter and ring width) are negatively correlated with density (basic and at 12% humidity) and modulus of elasticity but positively with heartwood proportion. No significant relationship exists between these two last traits. Pilodyn measurements are negatively and moderately linked to basic density but ranking provenances for wood density using pilodyn measures seems not too bad as Spearman rank correlation coefficient reaches 0.65^{**}. Density (12%) is highly correlated with MOE.

Conclusions are expressed in the same way at the provenance level (Table V and Fig. 2a & b).

DISCUSSION

The scarcity of published results on larch wood properties and the multiplicity of ways by which they are obtained (age and number of trees, methods of determination, etc) make it difficult to position our results.

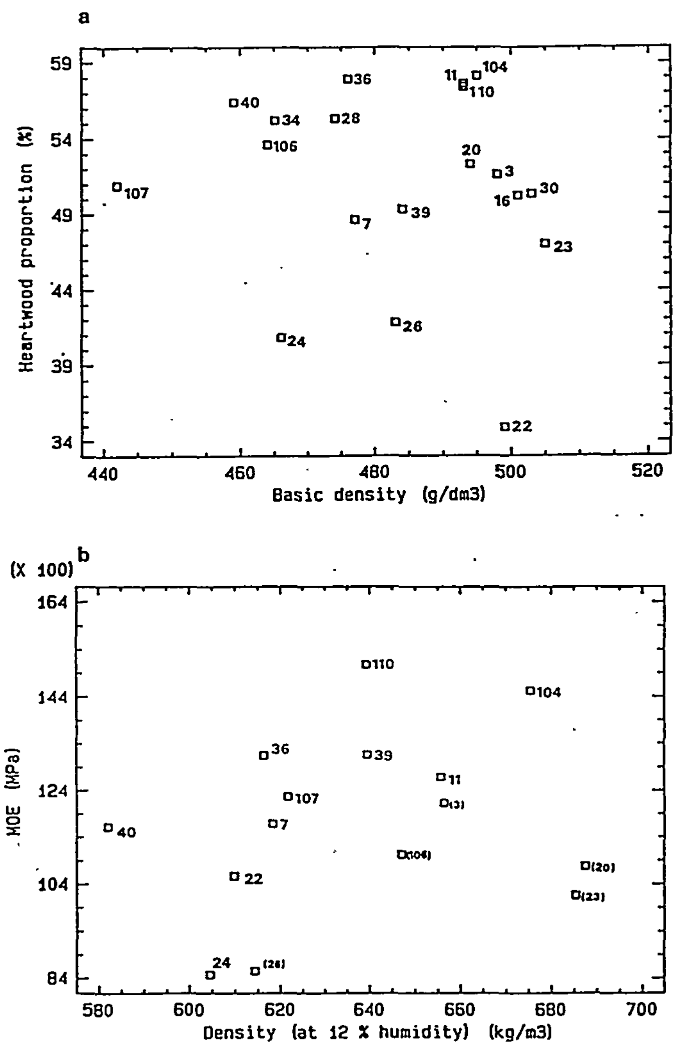

Fig. 2.a, b. Relationships at the provenance level between (a) basic density and heartwood proportion and (b) between density at 12 % humidity and Young modulus of elasticity.

For wood density at 12 % humidity, table VI indicates for material of closest age, an average density at Coat-An-Hay systematically higher than in other studies but comparable to results reported by Pearson and Fielding (1961) in South Scotland.

Table VI. European larch wood density (at 12 % humidity) in the literature

Site	Country	Age	Density (Kg/m^3)	Reference
Gahrenberg	D	28	460.4	Reck (1980)
Coat	F	34	635.8	
S.Scotland	GB	16-30	616.1	Pearson & Fielding (1961)
W.Scotland-Wales	GB	26/32	538.3	(idem)
SE.England	GB	25/50	555.0	(idem)
F.F.R.I	SF	50	579.0	Hakkila & Winter (1973)

For Young modulus of elasticity, our results are more in the range of published data but obtained with a different technique. Lavers (1969) reports a value of 9900 +/- 2230 MPa for European larch in Great-Britain. A previous study at Coat-An-Noz at 30 years indicates a Young modulus of 9305 (+/- 3185) MPa but with a different technique. For various hybrids with Japanese larch, MOE varies between 9300 and 13100 MPa according to Miyajima and Hasegawa (1978) for samples at different humidity.

Classical relationships between main wood quality traits are found in our study both at the individual and population levels : positive between wood density and MOE and negative between ring width (and so vigour) and both wood density and MOE. Similar results have been found by Miyajima and Hasegawa (1978) for hybrid larch and by Koizumi et al. (1990) for Japanese larch.

As for most traits studied so far (Schober, 1985 ; Weisgerber and Sindelar, 1992 ; Pâques, 1994), variability between provenances of European larch has been put into evidence in this study for wood parameter characteristics, even though the numbers of populations and trees included in this study were limited. Its importance both at the inter- and intra-population levels varies according to traits : proportion of heartwood and modulus of elasticity seem highly variable while wood density traits appear much less variable.

While variability subsists within geographic zones of European larch, trends for clinal variation can be seen from figures 1a & c for some wood traits : both the proportion of heartwood and its modulus of elasticity increase from the South-West to the North-East of European larch natural range. That is to say that the most vigourous populations from Central Europe are also characterized by two important and favourable wood quality traits : strength and proportion of heartwood, the durability of which is highly appreciated in outdoor use. At the opposite, the slower growing populations from the French Alps have less heartwood, a lower strength but on average a higher density.

The characteristics of the wood of the Central Polish provenance are somehow amazing : with one of the highest density, Grojec has also the highest modulus of elasticity and the highest proportion of heartwood. For the latter trait, this result is at the opposite of Schreiber's (1994, in Sindelar, 1992) conclusions in which Central Poland larch populations had the lowest volume of heartwood, the Alpine ones were intermediate and the Sudetan had the highest volume. This raises the question whether Grojec is really representative of Central Polish larch.

The interest of the hybrid between European and Japanese larch (110) is put forwards in this study (Fig. 2a & b) : with the fastest growth in this experiment (Pâques, 1994), it has one the highest proportion of heartwood (and durability ?) and though its wood density is a bit above the global mean, it has the highest modulus of elasticity (strength) ; it is very similar to

Japanese larch (provenance 36). The Sudetan provenance Zabreh (39) shares also the same favourable properties of middle density with high MOE.

The hybrid tested in this study is obviously not representative of all hybrids as the literature cites several cases where hybrids are intermediate between pure species for wood density (Nanson and Sacré (1978), Deret and Keller (1979), Lavers (1969)) or superior to both species (Langner and Reck (1966), Reck (1980)) or inferior (Reck (1977)). The same is true for Young modulus (Deret and Keller (1979), Lavers (1969)).

This study brings for the first time in France results on wood properties of European larch from a comparative provenance trial planted at low elevation. Due to its age and the current status of the plantation, these results must be considered as preliminary. They must be confirmed over as many sites as possible of the international IUFRO network to include a larger set of natural populations. Several traits of importance will have to be included such as shrinkage and durability, both arguing against or for larch wood use. Finally, wood qualities of fast growing lowland larch provenances compared to slow growing highland origins need to be precised. As with wood of Douglas fir from European forests compared to the one from old growth forests in the USA, fast growing provenances of larch from Central Europe, which are recommended for plantation in France at low elevation, might indeed produce a quite different raw material.

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SUDETIC LARCH IN GERMANY
RESULTS OF PROVENANCE AND PROGENY RESEARCH

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SUMMARY

There are only a few older sources of Sudetic larch in Germany. They distinguish themselves by outstanding growth and low susceptibility to canker.

This impression was confirmed by results of provenance research. The Sudetic larch tested in comparison with numerous other provenances proved to be fast-growing, site-tolerant, to a large extent insusceptible to canker, with straight but also slightly to moderately curved stems. The Sudetic provenances behave remarkably uniformly as regards these characteristics.

In addition to provenance research investigations have been going on for a long time in Germany into individual differences within the Sudetic larch populations. A report is given on the results of progeny tests from free and controlled pollination, using the example of a seed orchard consisting of 54 clones. We point also to possibilities for improving stem quality by selection steps.

The results of provenance and progeny research on Sudetic larch are in the meantime being put to use to a large extent in practical forestry. The forest administrations of various federal lands recommend the use of reproductive material of Sudetic origin and from seed orchards.

Keywords: Sudetic larch, cultivation experience, provenance comparison, progeny tests, "Tested Reproductive Material" from seed orchards.

1. Distribution and main areas of cultivation of European larch (*Larix decidua* Mill.) in Germany

The natural range of European larch extends to Germany only in the Bavarian Alps. All the other occurrences of larch in this country are due to artificial cultivation.

However, the advantageous silvicultural and wood-technological characteristics of this tree species were decisive for its early spread by man beyond its natural range. In Franconia, for example, larch afforestation was provably carried out already at the end of the 17th and beginning of the 18th century (ELSNER 1966).

Soon after this cultivation was extended to many other forest regions of the country. This took place at first without detailed knowledge of larch's specific site requirements. Only later was it perceived that good growth is achieved preferably in continental to sub-continental climatic conditions, on soil with a good water retention capacity and sufficient aeration.

Until the present day European larch is cultivated outside ist natural distribution area mainly mixed with other tree species, most frequently with *Fagus silvatica.* Beech is characterised by comparatively slow juvenile growth, high shade tolerance and good ground shading. Both tree species therefore complement each other in their ecological behaviour within the same rotation period.

2. Provenances of the older larch plantations

The older plantations outside the natural range in Germany originated provably or presumably primarily from reproductive material from Alpine provenances (PUCHERT 1967). The seed offered for sale by clever traders came mainly from larch sources in the region around Innsbruck and Imst in Tyrol and from Kärnten and Vorarlberg.

Yields in both volume and value from the stands of alpine origin vary: good results were often obtained from the first seed harvested from lower positions at the edge of the Alps. Later plantations using seed chiefly from higher harvesting areas in the inner Alps led however to considerable failures. The use of unsuitable provenances, errors in site selection and silvicultural treatment are seen today as possible causes for this failure (numerous literature references on this subject, comp. WEISGERBER, ŠINDELÁŘ 1992).

Compared with the common larch stands from Alpine provenances there are relatively few older plantations in Germany, which originate provably or probably from Sudetic provenances. Some of the provenances have distinguished themselves by especially vigorous growth and the quality of their timber. They have therefore been approved for seed harvesting as 'special provenances' (e.g. 'Harbker Lärche', 'Driburger Lärche', 'Schweckhauser Lärche').

On account of the impressive growth performance and low canker susceptibility (*Trichoscyphella willkommii*) of these older plantations MÜNCH (1933, 1936) already recommended planting Sudetic larch in preference to Alpine larch.

MÜNCH's perceptions and suppositions were later largely confirmed, in a modified form, by comparative provenance trials (i.a. RUBNER 1938, 1941; ZIMMERLE 1941; DENGLER 1942; SCHOBER, FRÖHLICH 1967). It was shown above all that the cultivation of high mountain provenances in low lying situations results in poor growth, early flushing and susceptibility to late frost. On the other hand, Sudetic larch, but also larch provenances from valleys on the eastern and northern edge of the Alps, suited the cultivation requirements considerably better, especially in the lower mountain regions of Germany.

3. Sudetic larch in provenance comparison

3.1 Comparison with provenances from other sub-areas of the natural larch range

Research work which was based initially on just a few provenance trials was able to be expanded and intensified in the following time. Important findings were reached, especially through participation in the two big IUFRO trial series of 1944 and 1957/58. Besides other authors, SCHOBER (1977, 1981, 1985) gave comprehensive reports.

In brief the following statements can be made on the most important characteristics of yield, quality and stability of the larch provenances from the Sudetic Mountains contained on the German trial plots.

Growth

In height growth, and to a lesser extent also in diameter and volume growth, the Sudetic larches exhibit a varying degree of superiority to the other larch provenances; in many cases the superiority is unmistakeable. The difference in performance is particularly striking when they are compared with high mountain provenances from the central southern and southwestern Alps.

The superior growth of Sudetic larch is less marked when compared with larch from the eastern Alps and from the Tatra Mountains. Provenances from Poland and the Sudetic Mountains are roughly equal.

Site tolerance

Determination of ecovalence enables statements to be made on the adaptation of the provenances to the particular site conditions. Of decisive importance are the relations between the growth of a particular provenance and the mean growth potential of the site in question.

According to investigations by DIETZE (1976) Sudetic larch possesses high ecovalence and thus good adaptability to different site conditions. This behaviour suggests considerable genetic flexibility, which is plausible only when there is great genetic diversity and a high degree of heterozygosity.

In contrast to the Sudetic larches provenances from other sub-areas of this tree species show a varying differentiation in site tolerance; it is noticeably strong in the case of Alpine larch.

Larch canker

Spread and intensity of attack by the canker pathogen *Trichoscyphella willkommii* vary according to the specific provenance and are negatively correlated to growth.

Only slight symptoms of the disease were visible among the provenances from the Sudetic Mountains, as also among those from the eastern and northern edge of the Alps, and especially from Poland. The central and southwest Alpine high altitude provenances on the other hand showed a medium to strong predisposition to the disease.

Stem shape

Straightness of stem and growth intensity are evidently not correlated positively in the way that had been hoped for from an economic standpoint. The Sudetic provenances which achieved good to very good assessments for other characteristics often develop only average stem shapes with slight to moderate crookedness. These larches thus perform better than the Polish larches contained in the trials but distinctly worse than some provenances from the northern and eastern Alps (e.g. Wienerwald).

Total assessment

The total assessment of all findings known to date on provenance research with *Larix decidua* makes us realize that there are no ideal provenances from the standpoint of forest management. The good growth performance and low susceptibility to canker of the Sudetic larches however could also promise a high yield in value if targeted thinning operations in the course of stand development succeed in improving their stem shape.

Compared with its growing behaviour in its country of origin (comp. i.a. ŠINDELÁŘ 1989, 1992) the Sudetic larch proves remarkably well growing and reliable in yield even at a great distance and on different sites. These provenances are evidently equipped with particularly efficient genetic adaptation systems which enable them to react flexibly even under considerable environmental changes.

3.2 Comparison of Sudetic provenances with one another

The Sudetic larch is represented by five provenances in the IUFRO-trial of 1957/58. They exhibit strikingly similar growing behaviour on all the trial plots under our care (7 low mountain sites in altitudes between 375 and 850 m) (WEISGERBER 1992).

Fig. 1 shows the relative heights of the Sudetic provenances (lower diagram) spread over a scale of twelve grades from < 50 % to > 150 %. These larches are characterised by their above average growth and their almost uniform height grading.

As a comparison the upper diagram of Fig. 1 contains five provenances from different regions of the eastern, northern and central Alps. These larches fall, as is to be expected, into distinctly different height grades.

The Sudetic provenances are also characterised by almost uniform group behaviour as far as good site adaptability and low canker susceptibility are concerned.

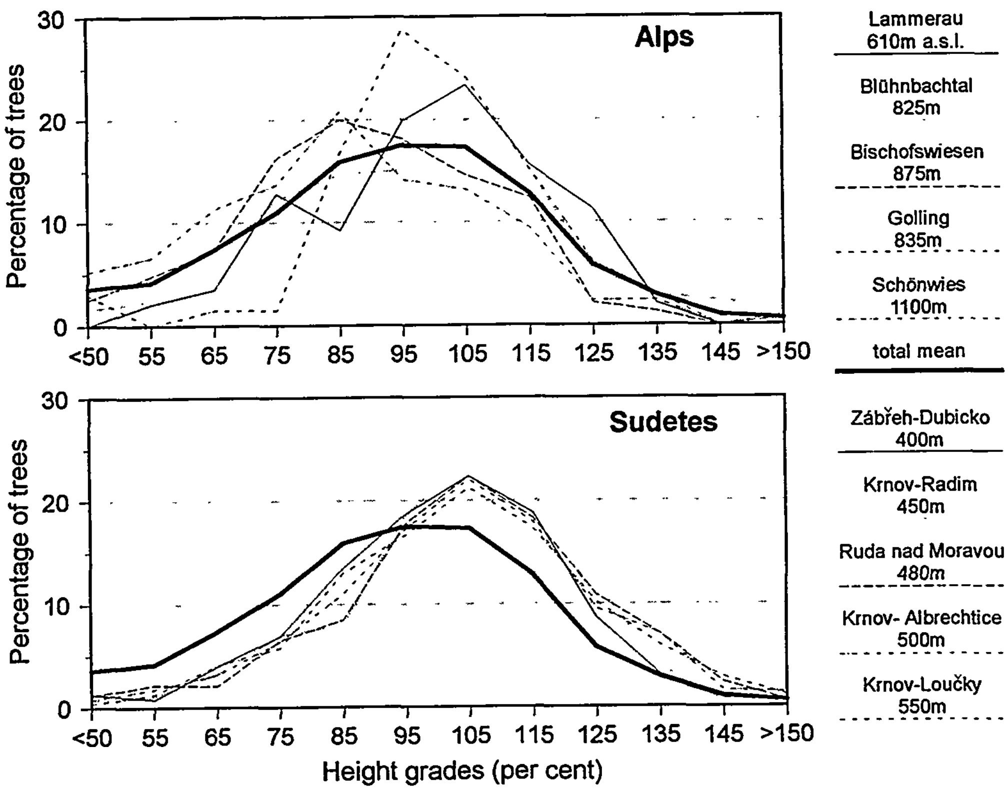

Fig. 1: Relative heights among provenances of European larch from the Alps and the Sudetic Mountains. IUFRO trial on seven plots at age 21

As regards stem shape, Fig. 2 illustrates the slight differentiation between the Sudetic larches. In this characteristic too they thus differ clearly from three Alpine provenances likewise presented.

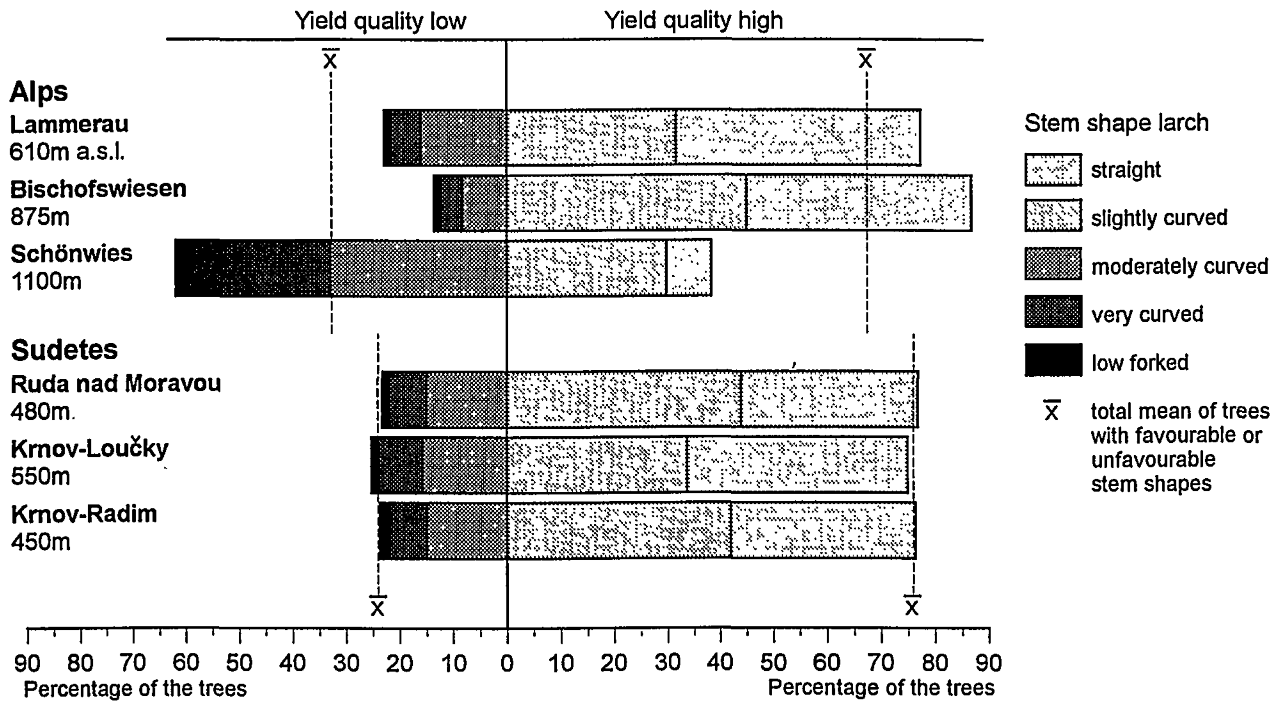

Fig. 2: Stem shapes in five classification levels and influences on yield quality among provenances of European larch from the Alps and the Sudetic Mountains. IUFRO trial on seven plots at age 21

Fig. 2 also enables rough indications of yield quality to be given. To simplify matters it is assumed that the stem shapes 'straight' and 'slightly curved' are positive according to economic criteria whereas the stem shapes 'moderately curved', 'very curved' and 'low forked' are judged negative.

The uniform behaviour of important quantitative and qualitative characteristics is therefore typical for the Sudetic provenances examined. However one cannot conclude from this finding that larch from the Sudetic Mountains is in all cases site-tolerant, vigorous, of superior performance and thus always suitable for cultivation in Germany. It must be born in mind particularly that intensive international seed trade had an effect on afforestation measures in the Sudetic region already at the middle of the last century. Thus not only indigenous seed but also seed from the Alps and the Tatra Mountains were used for larch cultivation in the Sudetic Mountains. In the case of the provenances under examination we assume however that they are exclusively indigenous larch sources.

4. Progeny tests with selected trees

4.1 Aim, material and methods

In addition to provenance research work has been going on for a long time in Germany on individual differences within populations of Sudetic larch.

Phenotypically selected plus trees served as original material. They are cloned and examined for both their adaptability to varying conditions and their suitability for combination in crossing programmes. The results of the progeny tests are used for building up advanced breeding seed orchards whose main purpose is the creation of 'Tested Reproductive Material' as outlined in the relevant OECD and EU regulations.

For our research we had at our disposal, among others, 54 Sudetic larch clones in a seed orchard established in 1964 in Rotenburg, Hessia. The plus trees had been selected in the previous years in nine different forest districts in the Sudetic Mountains. In some cases they were the same original stands whose seed was also used for comparative provenance research (comp. Fig. 1 and 2).

From 1968 to 1976 a comprehensive programme of controlled crossings between the clones was carried out in the form of an incomplete diallel. The material created in this way was planted on 11 trial sites with a total area of 23 ha in 1979 (WEISGERBER 1983).

The trials enable in particular comparisons to be made between progenies from controlled and free pollination of the parent trees and commercial seed from well known larch provenances. In 1983, 1987 and 1991 all trial plants were assessed regarding essential quantitative and qualitative characters.

As a supplement to the trial series another trial was set up in 1978 in two places using 7 seed lots from seed orchards of different provenances and commercial seed from 5 well known larch provenances. The seed required had been collected in 1974 for all treatments. Seed from the Sudetic larch seed orchard described above is included in this trial. The characteristics typical for growth behaviour were assessed in both places at 4-yearly intervals.

4.2 Results

RAU (1988) gave a report on the first results of the progeny test of 1978. It was seen that for the period of time observed until plant age 12 the larches originating from free pollination in the seed orchards were in many cases significantly superior in growth and shape to those originating from commercial seed. This is particularly true for the Sudetic larch from seed orchards.

An evaluation of the trial series of 1979 is currently being undertaken. Only a few partial results can be given in the course of this contribution.

Fig. 3 enables one to compare progenies from controlled pollination and plants from commercial seed (special provenances 'Dieburger Lärche', 'Driburger Lärche', 'Schlitzer Lärche'). The values given for height and stem shape refer to plant age 10 and were collected at three test plots of the subtrial A and B respectively.

As regards height there is strikingly uniform superiority (except at the cultivation site Schlitz) on the part of the crossing progenies to the plants from commercial seed from well-known provenances. In Melsungen and Neuhof in particular all Sudetic larch treatments proved to be significantly faster growing (Statistical prodedure: SAS 6.08, Proc Mixed).

As regards shape characteristics no significant differences could be established between the crossing progeny group and the group of commercial seed treatments. The proportion of plants with advantageous stem shapes (straight or slightly curved) however varies greatly among the crossing progenies according to treatment. This means that an improvement in the stem quality of Sudetic larch could obviously be achieved by selective measures. This knowledge can be used for example when establishing seed orchards for the production of 'Tested Reproductive Material'.

5. Discussion and conclusions

Sudetic larch was probably cultivated in Germany for the first time in the middle of the 18th century. In particular the special provenance 'Harbker Lärche' is traced back to seed which was supplied at that time from the region around Jägerndorf/Sudetic Mountains.

As far as the use of Sudetic provenances is quite certain cultivation experience in forestry practice has been positive for a long time. BORCHERS (1967) praises, among other things, the following characteristics: slim growth, low tendency to sabre-shaped stem, low susceptibility to canker, shade tolerance, insensitivity to lateral pressure, natural regeneration ability, site tolerance.

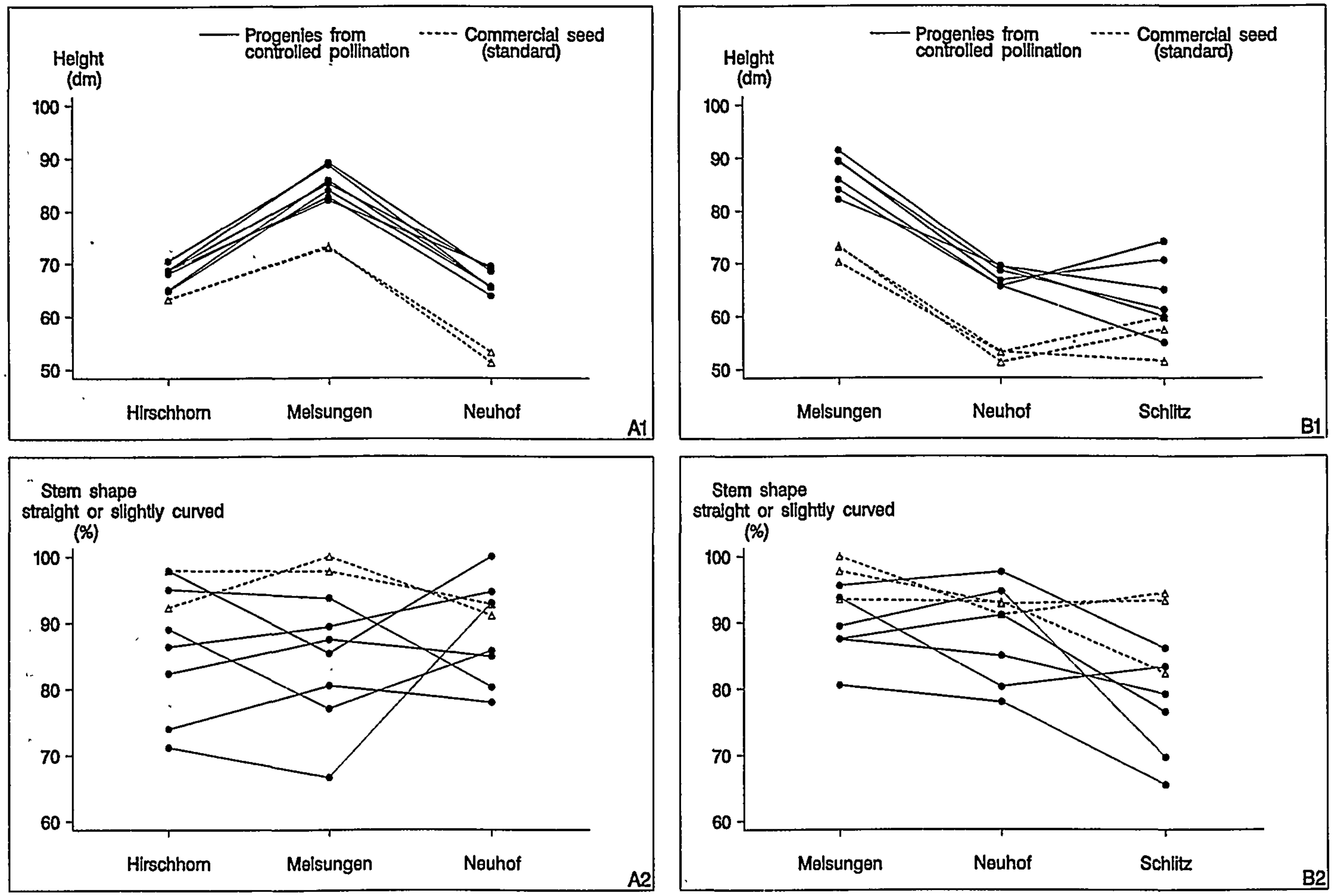

Fig. 3: Progenies from controlled pollination of Sudetic larch clones and from commercial seed. Mean heights and percentage of trees with favourable stem shapes at age 10. Subtrials A and B with 3 plots, respectively.

Earlier cultivation experience was on the whole confirmed by systematic provenance trials. In particular participation in the two big IUFRO trial series of 1944 and 1957/58 led to valuable knowledge on the volume and value yield of Sudetic larch.

On all the trial sites for which we are responsible the constant high growth potential of these larches as compared with other treatments is especially noticeable. Good site adaptability and high vitality combined with low susceptibility to canker ensure good cultivation chances on all sites on which European larch is of interest.

The only average stem quality of the Sudetic provenances might be explained by their fast growth. SCHOBER (1977) suspects that these larches are, on account of their fast growth in height, exposed to static stress from wind and snow pressure to an unusual degree. In all the Sudetic provenances we examined there are enough straight-stemmed trees which can be promoted by means of positive selection and promise a high yield in value.

The superiority of Sudetic larch to other commercially obtainable provenances can evidently still be considerably increased by cloning selected trees and establishing seed orchards. This is true also for stem quality: the larch originating from free pollination in the Rotenburg seed orchard distinguished themselves by significantly better stem shapes than the special provenances (RAU 1988).

The results of the progeny tests after controlled pollination show that further selection gains are possible. They can be used to establish an advanced breeding seed orchard.

Knowledge obtained from provenance and progeny research with Sudetic larch is in the meantime being used to a large extent in forestry practice. In accordance with cultivation recommendations drawn up by the forest administration of various federal lands many forest enterprises are making use of the possibility of planting Sudetic provenances to establish mixed stands, especially with beech. In addition, the Rotenburg seed orchard has been officially approved for the production of "Tested Reproductive Material". This means that provably best suited propagation material of European larch on a broad genetic basis will be available in future for practical forestry.

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MARIAN KULEJ

GROWTH DYNAMICS VARIATION OF DIFFERENT LARCH PROVENANCES UNDER THE MOUNTAIN CONDITIONS IN POLAND

Introduction and study objective

Acquiring the knowledge about the variation of forest tree species is one of the basic problems in selection work undertaken in order to increase the productivity of forests. Within the range of distribution of the individual species there are whole areas or communities of individuals which in their external and internal structure (genotype set) differ considerably from one another. Thus, the economic usability of these populations in a given area is not uniform. They differ in respect of adaptability to given climatic and soil conditions, as well as of productive efficiency. It is therefore necessary to search within a given species for such populations which are best suited to particular conditions.

This problem is of special importance in case of larch being a fast growing species and having and island distribution in Poland (Bałut, 1962, 1967; Kocięcki, 1969). The existence of biological differences among the larches of Poland has been already pointed out many times. The results of research in this respect have been reported by foreign (Bornebusz, 1948; Göhrn, 1956; Haasemann and Schönbach, 1970; Kočova, 1974; Križan, 1975; Šindelàr, 1974; Štastný, 1972; Tschermak, 1935; Wachter, 1961) as well as

Polish (Andrzejczyk and Bellon, 1992; Kocięcki, 1962, 1969; Kulej, 1983, 1985, 1986, 1989, 1991; Kulej and Niedzielska, 1990; Rzeźnik, 1980) authors. They stress the necessity for continuation of such research in comparative areas with different climatic conditions. Such comparative studies were initiated in Poland by the Forest Research Institute in Warsaw by establishing in 1967-1968 five experimental areas in order to determine a silvicultural usability of larch under different natural and forest conditions of this country. The results presented in this paper are part of these studies. In our country this is the first provenance experiment with larch under the mountain conditions involving a large number of larch provenances from the entire area of Poland. The objective of the present work was to determine the growth variation of larch of selected Polish provenances under the mountain conditions of Gorce Mts. and Beskid Sądecki Mts. exemplified by the experimental area in Krynica.

Materials

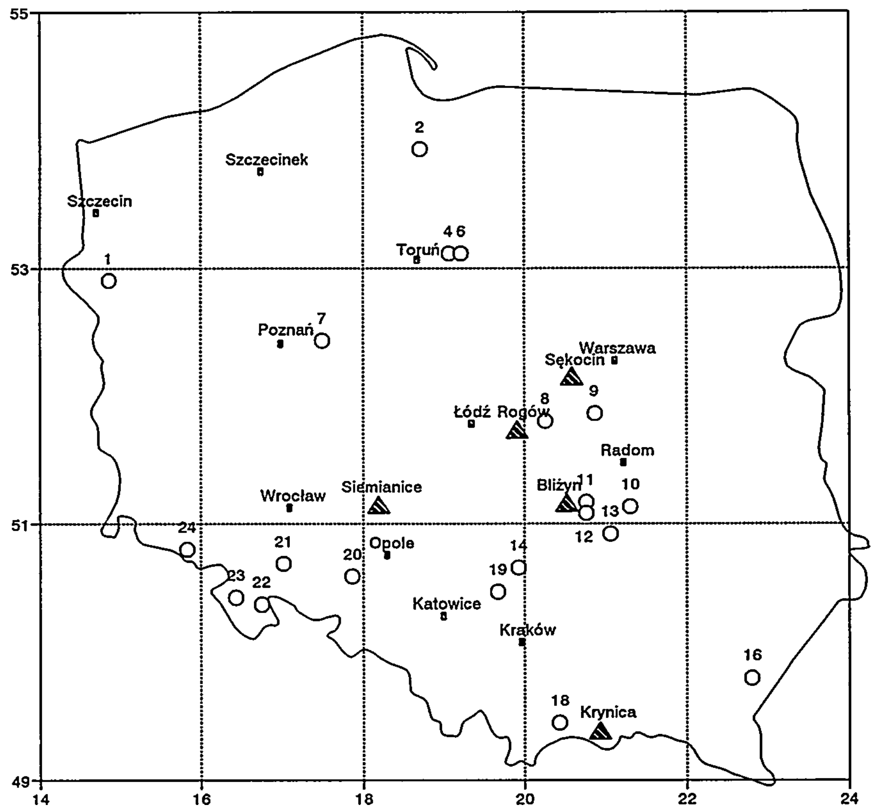
The study involved 20 larch provenances from the entire area of Poland. Characteristics of stands and parent trees of the experiment are shown in tab. 1, and their location on fig. 1.

The experimental area was established by professor S. Bałut in 1968 in Krynica, and is located in the Sądecki Beskid Province of the Carpathian Forest Region (Region No. VIII). It is situated at 785 m above the sea level, i.e. in the middle part of the lower montane zone. It is characterized by quite even physiographic and soil conditions.

TABLE 1. Characteristics of forest stands and parent trees in the Polish Experiment on Larch Provenances 1964/65. Experimental area in the Forest Experimental Station in Krynica

No of provenances	Name of provenances	Forest district	Cutting section	Forest site type	Geographical coordinates		Altitude above sea level	Characteristic of trees from harvested cones			
					longitude	latitude		Number of trees	Age of trees	Height [m]	b.d.h. [cm]
1	Myślibórz Północ	Zieleniec	391, 40b	LM	52°54′	14°52′	50·75	20	115	34	43
2	Pelplin	Opalenie	64d	LM	53°56′	18°43′	50·75	5	120	38	52
			87c					15	110	37	45
4	Konstancjewo	rez. Płonne	76g	BMśw	53°07′	19°04′	50·75	10	35	15	18
6	Konstancjewo	rez. Tomkowo		BMśw	53°07′	19°04′	50·75	20	120·160	24	50
7	Czerniejewo	rez. Bielawy	76j	LM	52°26′	17°30′	100·120	12	90	33	58
8	Rawa Mazowiecka	rez. Trębaczew	90cc$_1$	LM	51°48′	20°15′	180	20	90	26	35
9	Grójec	Mała Wieś	158e	Lśw	51°52′	20°52′	180	20	120	31	40
10	Marcule	rez. Piotrowe Pole	135c	LM	51°08′	21°15′	200·220	3	133	27	52
			157d					17		28	58
11	Skarżysko	Ciechostowice	129a	LM	51°10′	20°46′	350·400	4	200	30	58
			130a					2	140	10	61
			128a					1	250	30	56
			86a					1	60	18	51
			107a					1	65	17	
			87a					6	50	16	
			88c					2	130	38	
			89a								
12	Bliżyn	Jastrzębia	217b	BM	51°05′	20°46′	280·320	1	120	31·45	37·70
			216b					3			
			242c					2			
			192a					8			
			194a					3			
			190d					1			
			187a					2			
13	Świętokrzyski P.N.	rez. Góra Chełmowa	A	BM	50°55′	21°04′	300·400	20			
14	Moskorzew	Feliksówka	351	BMśw	50°39′	19°56′	250	18	140	30	50
16	Hołubla	Łętownia	45b, 49i	Lśw	49°48′	22°48′	300·350	20	90	35	55
18	Krościenko	rez. Księży Las	62i	LG	49°27′	20°26′	640·660	20	45	16	17
19	Pilica	rez. Smoleń	170g	LM	50°28′	19°40′	450	6	80	25	29
20	Prószków	Jaśkowice	120f	LM	50°35′	17°52′	180	20	143	35	52
21	Henryków	Muszkowice	282g	Lśw	50°41′	17°01′	300·350	20	95	33	56
22	Kłodzko	Ołdrzychowice	202a	LM	50°22′	16°45′	300·450	20	110	30	38
23	Szczytna Śląska	Borowina	322b	BMG	50°25′	16°26′	500·550	20	105	27	47
24	Kowary	Jedlinki	299a	LMG	50°48′	15°50′	500·550	20	115	27	30

Lśw – fresh decidous site; LM – mixed coniferous forest site; BMśw – fresh mixed coniferous forest site; BM – mixed coniferous forest site; LG – mountain decidous forest site; BMG – mixed decidous mountain forest site; LMG – mountain mixed decidous forest site.



1 - 24 - numbering of the provenances in the experiment

○ - location of provenances

▲ - situation of observation areas

☒ - seats of Regional Head Offices of State Forests

Fig. 1. Distribution of the investigated larch provenances in Poland
Experimental plot I. Sękocin II. Bliżyn III. Rogów IV. Krynica V. Siemianice
Provenance

1 - Myślibórz Płn.
2 - Pelplin
4 - Konstancjewo (R. Płonne)
6 - Konstancjewo (R. Tomkowo)
7 - Czerniejewo
8 - Rawa Mazowiecka
9 - Grójec
10 - Marcule
11 - Skarżysko
12 - Bliżyn
13 - Świętokrzyski P.N.
14 - Moskorzew
16 - Hołubla
18 - Krościenko
19 - Pilica
20 - Prószków
21 - Henryków
22 - Kłodzko
23 - Szczytna Śl.
24 - Kowary

Each provenance was planted in 5 replications assuming the rule of Latin rectangle in distribution of provenances over the experimental area. Thus, the entire material was divided into 100 plots, with 121 individuals in each plot. In total 12 100 larch trees were planted in the experimental area.

Methods

Characterization of the growth dynamics of the provenances investigated has been based on the height and diameter measurments taken when trees were 5 (1969), 8 (1972), 11 (1975), 15 (1979), 20 (1984) and 25 (1989) years old (i.e. six study periods). The diameter of trees 5 and 8 years of age was measured at the root collar, while in subsequent years at the breast height.

The entire material was characterized using arithmetic mean, standard deviation and coefficient of variation. The distribution of mean values of the characters analized were tested with Kolmogorov's test and it was found that they follow a normal distribution. The means of these characters were subjected to analysis of variance and Snedecor's test (Perkal, 1967).

The height and b.h.d. of larch provenaces investigated at the age of 25 were expressed in standardized units (Perkal, 1967) using growth classes. One standard deviation was assumed to be a class limit. In order to characterize the different larch provenances in respect of height and b.h.d. jointly the „growth index" was assumed, basing on standardized elements of these characters.

Mutual dependences of analized characters of larch provenances during the consecutive study periods were described using the matrix of autocorrelation coefficients (Weber, 1972).

The growth of individual larch provenances has also been presented using proper curves. This paper contains only the most characteristic examples. For height growth approximation the Korf's functions (Korf at all, 1972) were utilized.

$$y = Ae \frac{k}{(1-n)x^{n-1}}$$

where:

y - height
x - age
e - base of a natural logarithm
A,k,n - parameters of functions

The accuracy of growth approximation using above functions was evaluated calculating the sum square of deviation between actual and compensated height. For each larch provenance analized the age of height growth culmination was determined as well as a corresponding value of the annual growth.

Results

Growth characters of larch provenaces investigated

Height

The best provenances as regards the height at the age of 5, 8, 11, 15, 20 and 25 years turned out to be the larches from Prószków and Kłodzko (tab. 2). The lowest height was recorded for larch from Pelplin, Grójec and Marcule.

Table 2. Mean height of larch of 20 provenances during 1969-1989. Experimental area in the Forest Experimental Station in Krynica

No of provenances	Name of provenances	Years							
		1969 - 5 yeras	1972 - 8 yeras	1975 - 11 yeras	1979 - 15 yeras	1984 - 20 yeras	1989 - 25 yeras		
		h [cm]	h [cm]	h [cm]	h [m]	h [m]	h [m]	$(h-\bar{H})/S$	growth class
1	Myślibórz-Północ	99,24	266,95	491,30	8,25	10,68	13,64	0,61	good
2	Pelplin	97,64	246,28	446,30	7,72	10,36	13,25	0,09	average
4	Konstancjewo-Płonne	104,72	260,47	477,38	8,12	10,75	13,71	0,71	good
6	Konstancjewo-Tomkowo	104,30	259,53	455,64	7,65	11,07	13,57	0,52	good
7	Czerniejewo	107,28	257,41	457,20	7,79	11,23	13,57	0,52	good
8	Rawa Mazowiecka	104,79	251,43	446,40	7,58	10,16	12,56	-0,83	poor
9	Grójec	105,49	261,38	450,48	7,42	10,03	11,97	-1,61	bad
10	Marcule	103,55	230,53	394,58	6,75	10,04	11,01	-2,89	bad
11	Skarżysko	115,54	278,58	486,58	8,19	10,67	13,77	0,79	good
12	Bliżyn	106,33	260,74	460,18	7,70	10,40	13,27	0,12	average
13	Świętokrzyski P.N.	113,38	285,00	500,50	8,05	10,91	13,36	0,24	average
14	Moskorzew	111,29	280,13	494,78	8,04	11,17	13,54	0,48	average
16	Hołubla	110,62	285,38	492,32	7,93	11,13	12,70	-0,64	poor
18	Krościenko	103,09	282,46	478,26	7,90	10,47	12,84	-0,45	average
19	Pilica	103,84	265,56	467,38	7,67	10,79	13,00	-0,24	average
20	Prószków	120,37	298,59	530,02	8,66	11,19	14,56	1,84	very good
21	Henryków	109,65	263,34	465,80	7,73	10,76	12,58	-0,80	poor
22	Kłodzko	119,80	313,59	547,20	8,52	11,83	13,68	0,67	good
23	Szczytna Śląska	117,79	282,11	509,72	8,39	10,56	13,81	0,84	good
24	Kowary	108,95	282,84	512,01	8,46	10,47	13,30	0,16	average
Mean - $\bar{H}$		108,38	270,62	478,20	7,93	10,73	13,18	–	–
Standard deviation - S		6,25	18,54	33,27	0,43	0,44	0,75	–	–
Coefficient of variance - V%		5,77	6,85	6,96	5,42	4,11	5,67	–	–

After 25 years the best height was achieved by larch from Prószków (14,56 m), Szczytna Śląska (13,81 m), and Skarżysko (13,77 m), while the worst by the following provenances: Marcule (10,01 m), Grójec (11,97 m) and Rawa Mazowiecka (12,56 m). The difference in the average height between provenances achieving the highest and the lowest value of the analized character was 3,55 m which amounted to 24,4%.

On the basis of the results obtained it was concluded that larch of the provenances tested forms a material statistically heterogenous and differentiated as regards the growth in height (tab. 3). This variability occurred already when trees were 5 years old and persisted with age, which is reflected by the coefficient of variation V% of this character varying from 4,11% to 6,96%.

TABLE 3. **Value of F in Snedecor's test of variance analysis for tested growth characteristics of larch of individual provenances**

Analised characteristics	Years					
	1969	1972	1975	1979	1984	1989
Height	4,13[xx]	2,26[xx]	2,95[xx]	3,01[xx]	1,22	2,95[xx]
Diameter (d.b.h.)	1,79[x]	3,02[xx]	2,98[xx]	2,52[xx]	2,11[x]	2,54[xx]
Growth index	2,22[xx]	2,52[xx]	2,74[xx]	2,70[xx]	1,90[x]	1,96[x]

[x] – significant difference for α = 0,05
[xx] – significant difference for α = 0,01

The provenances achieving the highest and the lowest heights differ significantly from most of other provenances (Kulej, 1983; 1989).

Analizing the heights of individual provenances of larch, 25 years of age, expressed in standardized units it was concluded that only larch from Prószków showed a very good growth. On the other hand the very bad provenances with regard to height growth were those from Grójec and Marcule.

There was also an autocorrelation dependence between the heights of provenances in consecutive study periods (tab. 4). This dependence was inconsiderable for the age of 5 and 8 years, and also 5 and 11 years. On the other hand there was a high correlation between heights of larches 8 and 11 years old (r = 0,924), and 11 and 15 years old (r = 0,949).

TABLE 4. Matrix of coefficients of autocorrelation between height of larch of 20 provenances in experimental area in the Forest Experimental Station in Krynica at the age of 5, 8, 11, 15, 20 and 25 years

Age in years	5	8	11	15	20	25
5	1	0,437ˣ	0,421	0,606ˣˣ	0,555ˣˣ	0,438ˣ
8	0,437ˣ	1	0,924ˣˣ	0,644ˣˣ	0,676ˣˣ	0,596ˣˣ
11	0,421	0,924ˣˣ	1	0,949ˣˣ	0,667ˣˣ	0,739ˣˣ
15	0,606ˣˣ	0,644ˣˣ	0,949ˣˣ	1	0,570ˣˣ	0,856ˣˣ
20	0,555ˣˣ	0,676ˣˣ	0,667ˣˣ	0,570ˣˣ	1	0,611ˣˣ
25	0,438ˣ	0,596ˣˣ	0,739ˣˣ	0,856ˣˣ	0,611ˣˣ	1

ˣ – significant difference for α = 0,05
ˣˣ – significant difference for α = 0,01

Diameter at breast height

The mean diameters at root collar and d.b.h. of trees of individual larch provenances in consecutive study periods are shown in tab. 5. The larches from Kłodzko, Prószków and Moskorzewo were characterized by high d.b.h. values. The lowest diameters were achieved by trees from Marcule, Krościenko and Bliżyn.

TABLE 5. Mean diameter at root coolar and d.b.h. of larch of 20 provenances during 1969-1989*. Experimental area in the Forest Experimental Station in Krynica

No of pro-ve-nan-ces	Name of provenances	Years							
		1969 - 5 yeras	1972 - 8 yeras	1975 - 11 yeras	1979 - 15 yeras	1984 - 20 yeras	1989 - 25 yeras		
		d^x [mm]	d^x [mm]	$d_{1,3}$ [cm]	$d_{1,3}$ [cm]	$d_{1,3}$ [cm]	$d_{1,3}$ [cm]	$(d-\bar{D})/S$	growth class
1	Myślibórz-Północ	16,49	57,84	6,60	10,08	13,38	15,87	−0,24	poor
2	Pelplin	17,21	54,49	5,91	9,36	13,58	16,24	0,35	average
4	Konstancjewo-Płonne	18,43	57,84	6,27	9,52	13,24	15,87	−0,24	poor
6	Konstancjewo-Tomkowo	17,72	59,49	6,19	9,25	13,52	16,26	0,38	average
7	Czerniejewo	16,89	53,79	5,92	9,29	13,29	15,96	−0,09	average
8	Rawa Mazowiecka	18,58	56,63	6,08	9,44	13,70	16,46	0,70	good
9	Grójec	19,47	57,25	6,18	9,24	13,31	15,70	−0,51	poor
10	Marcule	17,53	53,55	5,57	9,52	13,58	16,19	0,27	average
11	Skarżysko	18,67	57,66	6,41	9,80	14,03	16,37	0,56	good
12	Bliżyn	17,86	53,47	5,97	9,18	13,38	15,37	−1,04	poor
13	Świętokrzyski P.N.	20,84	61,58	6,46	9,14	13,77	16,36	0,54	good
14	Moskorzew	20,96	63,06	6,65	9,94	13,80	16,57	0,88	good
16	Hołubla	20,49	62,24	6,55	9,62	13,61	15,99	−0,05	poor
18	Krościenko	19,00	57,26	6,23	8,90	12,48	14,61	−2,27	bad
19	Pilica	18,44	57,64	6,28	9,59	13,73	15,94	−0,13	average
20	Prószków	19,19	61,28	6,85	10,27	13,76	15,74	−0,45	average
21	Henryków	19,19	58,80	6,20	9,34	13,65	16,21	0,30	average
22	Kłodzko	20,63	68,91	7,32	10,80	15,07	17,87	2,98	very good
23	Szczytna Śląska	17,53	55,97	6,34	9,83	13,27	15,45	−0,91	poor
24	Kowary	17,59	58,36	6,64	10,11	13,30	15,43	−0,95	poor
Mean - $\bar{D}$		18,64	58,36	6,33	9,61	13,57	16,02	–	–
Standard deviation - S		1,30	3,64	0,37	0,45	0,46	0,62	–	–
Coefficient of variance - V%		6,98	6,23	5,89	4,64	3,42	3,87	–	–

* - in 1969, 1972 diameter was measured at 10 cm above the ground

The larch 5, 8, 11, 15, 20 and 25 years of age formed a heterogenous and differentiated material (tab. 3). This differentiation, similarly as in case of height, was observed already when trees were 5 years old. When analizing the coefficients of variation a certain decrease in differentiation in respect of diameter (d.b.h.) may be observed when trees are getting older, from V% = 6,98% in 5[th] to V% = 3,87% in 25[th] year of life.

The greatest mean d.b.h. for trees 25 old was recorded for larch from Kłodzko (17,87 cm), and the amallest for larch from Krościenko (14,61 cm). The difference between these two is 3,26 cm i.e. 18,2%. The mean d.b.h. for the entire material was 16,02 cm. The d.b.h. of trees from Hołubla, Czerniejewo and Pilica approximated this mean. Taking into account the mean d.b.h. of the provenances after 25 years (expressed in standarized units) it was shown that only larch from Kłodzko belongs to the class of very good ones. The provenances from Rawa Mazowiecka, Skarżysko, St. Cross Mts. National Park and Moskarzewo may be accepted as good ones. On the other hand the larch from Krościenko is decidedly a worst provenance with regard to diameter (tab. 5).

The autocorrelation dependence for the diameter during the consecutive study periods is shown in tab. 6. It reaches the highest values at the age of 11 and 15 (r = 0,779), and 20 and 25 years (r = 0,907).

TABLE 6. **Matrix of coefficients of autocorrelation between d.b.h. of larch of 20 provenances in experimental area in the Forest Experimental Station in Krynica at the age of 11, 15, 20 and 25 years**

Age in years	11	15	20	25
11	1	0,779[xx]	0,578[x]	0,383
15	0,779[xx]	1	0,708[xx]	0,501[x]
20	0,578[x]	0,708[xx]	1	0,907[xx]
25	0,383	0,501[x]	0,907[xx]	1

[x] – significant difference for α = 0,05
[xx] – significant difference for α = 0,01

Growth index

As it has been mentioned above the larch of 20 provenances in the study area at Krynica forms a material significantly differentiated as regards the growth characters. About each provenance analized we may say that it belongs to a group of best or worst provenances in respect of height or diameter. However, not always a given provenance assumes the same position in respect of each of the characters mentioned above. For this reason, in order to evaluate the growth of individual larch provenances during the consecutive study periods, so called „growth index" was utilized. It takes into account both characters expressed in standardized units.

At the age of 25 years the highest value of growth index was attained by the larch of Sudeten provenance from Kłodzko (1,82). The larches from Prószków, Moskarzewo and Skarżysko also belong to provenances showing good height and diameter growth (fig. 2).

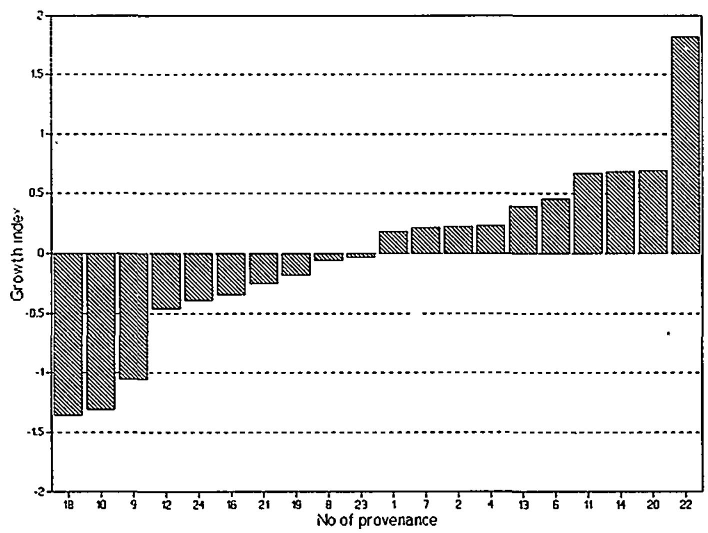


Fig. 2. Growth index of larch of investigated provenances at the age of 25 years. Experimental area in the Forest Experimental Station in Krynica.

On the other hand decidedly worst ones in this respect are provenances from Krościenko (-1,36), Marcule (-1,31), and Grójec (-1,06).

The analysis of variance and Snedecor's test showed a significant effect of genotype (provenance) on the growth variation of tested larch trees during the consecutive years of life. The dependence of growth of individual provenances described by the matrix of autocorrelation coefficients (tab. 7) persists during the entire 25-year period at the limit of statistical significance for $\alpha = 0{,}05$ and 0,01, reaching the highest values at the age of 8 and 11 ($r = 0{,}914$), and 11 and 15 years ($r = 0{,}932$).

TABLE 7. **Matrix of coefficients of autocorrelation between growth index of larch of 20 provenances in experimental area in the Forest Experimental Station in Krynica at the age of 5, 8, 11, 15, 20 and 25 years**

Age in years	5	8	11	15	20	25
5	1	0,831^{xx}	0,641^{xx}	0,429^{x}	0,604^{xx}	0,460^{x}
8	0,831^{xx}	1	0,914^{xx}	0,745^{xx}	0,732^{xx}	0,637^{xx}
11	0,641^{xx}	0,914^{xx}	1	0,932^{xx}	0,656^{xx}	0,668^{xx}
15	0,429^{x}	0,745^{xx}	0,932^{xx}	1	0,608^{xx}	0,704^{xx}
20	0,604^{xx}	0,732^{xx}	0,656^{xx}	0,608^{xx}	1	0,874^{xx}
25	0,460^{x}	0,637^{xx}	0,668^{xx}	0,704^{xx}	0,874^{xx}	1

^{x} – significant difference for $\alpha = 0{,}05$
^{xx} – significant difference for $\alpha = 0{,}01$

Curves and age of culmination of height growth of larch provenances tested

The following groups of provenances may be distinguished on the basis of height growth curves:

1. Provenances which as regards the height growth at the age of 5, 8, 11, 15, 20 and 25 years assume the positions above the compensated curve for the population investigated (but do not pass the compensated curve of value $\bar{X}$+0,5S) - Skarżysko, St. Cross Mts. National Park, Prószków, Kłodzko (fig. 3), Szczytna Śląska, Kowary.

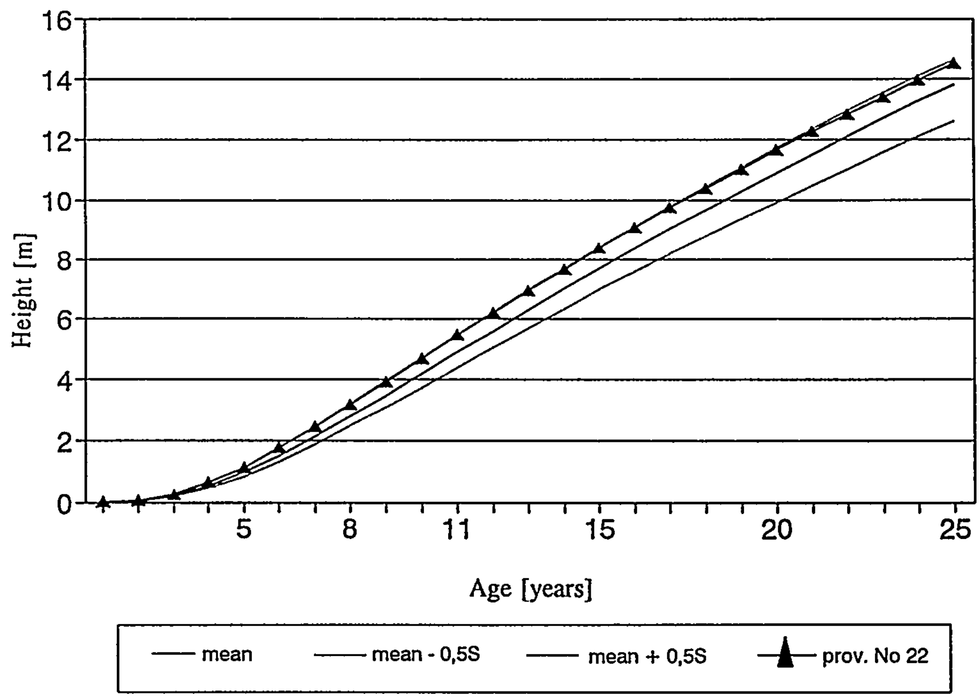


Fig. 3. Height growth curves of Kłodzko larch provenance

2. Provenances which as regards the height growth during the consecutive study periods assume the positions below the compensated curve for the population investigated, but do not pass the compensated curve of value $\bar{X}$-0,5S - Pelplin, Rawa Mazowiecka, Grójec, Pilica.

3. Provenances for which the height growth curves for early period of life (6-8 years) run below the curve for the population studied (but not below the compensated curve of value $\bar{X}$-0,5S), while at the age of 9 and 10 years are aligned with the compensated curve for the entire study material, and then run above it but not passing compensated curve of value $\bar{X}$+0,5S - Myślibórz Północ, Konstancjewo-Płonne.

4. Provenances for which the growth curves up to about 8 and 14 years of age assume the positions below the compensated curve for the population studied (not passing the compensated curve of value $\bar{X}$-0,5S). While at the age above 8 and 14 years become aligned with it, and then from about the age of 13 and 17 years run below it, but not passing the compensated curve of value $\bar{X}$-0,5S - Krościenko, Hołubla.

5. Provenances for which the growth curves become aligned twice with the compensated curve for the larch population investigated (tab. 8), and run during most of the entire 25-year period below it, not passing however the compensated curves of value $\bar{X}$-0,5S and $\bar{X}$+0,5S - Konstancjewo-Tomkowo, Czerniejewo, Bliżyn, Henryków.

6. Provenance which in respect of the height growth during the entire study period, i.e. from 5 to 25 years in age, assums the position below the compensated curve of value $\bar{X}$-0,5S - Marcule (fig. 4).

All larch provenances investigated had reached their height growth culmination (tab. 8). The earliest culmination took place in case of the larch from Kłodzko (10 years), and the latest in case of the larch from Henryków (16 years). The annual height increment fell within the interval from 0,60 m (Marcule) to 0,76 (Kłodzko).

TABLE 8. **Arrangement of larch provenances according to increasing age of height growth culmination**

No of provenance	Name of provenance	Age of height growth culmination [years]	Annual height increment at the moment of culmination [m]	Point of crossing of growth curves of a given provenance with adjustment curve of the population investigated [years]	
22	Kłodzko	9,93	0,76	–	–
24	Kowary	10,04	0,73	–	–
20	Prószków	10,32	0,77	–	–
16	Hołubla	10,56	0,70	17,20	–
18	Krościenko	10,57	0,69	12,60	–
9	Grójec	10,61	0,65	–	–
1	Myślibórz-Północ	10,63	0,76	8,95	–
11	Skarżysko	10,73	0,73	–	–
14	Moskorzew	10,88	0,73	–	–
13	Świętokrzyski Park Narodowy	10,92	0,72	–	–
23	Sztytna Śląska	11,16	0,74	–	–
8	Rawa Mazowiecka	11,28	0,67	–	–
19	Pilica	11,42	0,69	–	–
2	Pelplin	11,63	0,70	–	–
4	Konstancjewo-Płonne	11,68	0,74	10,24	–
10	Marcule	11,70	0,60	–	–
12	Bliżyn	12,02	0,70	5,19	23,37
6	Konstancjewo-Tomkowo	13,34	0,69	4,91	23,28
7	Czerniejewo	13,68	0,70	5,56	19,60
21	Henryków	16,07	0,69	8,43	20,82

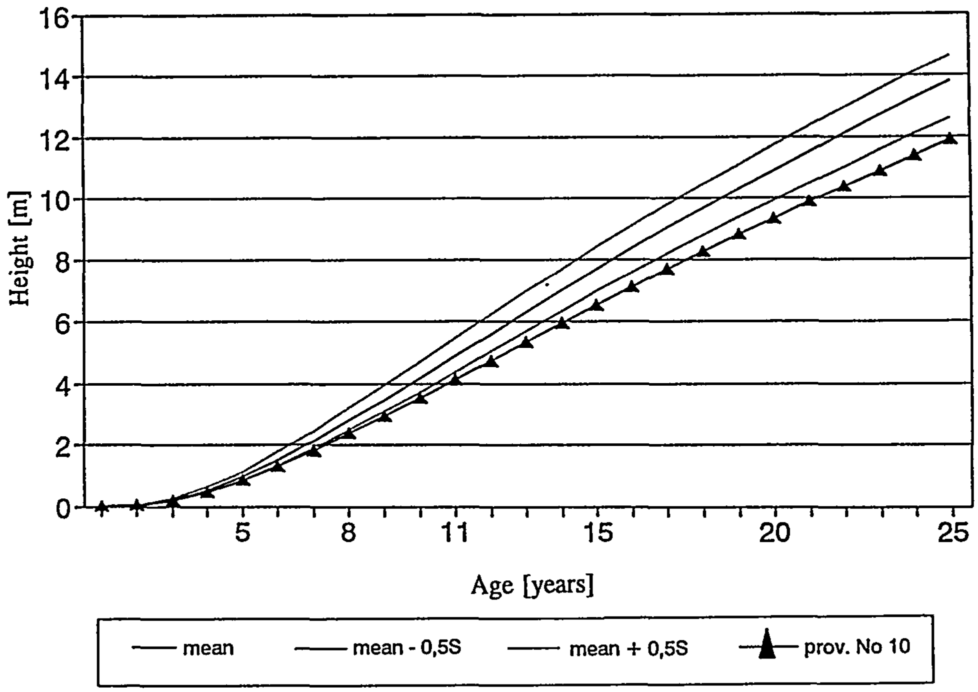


Fig. 4. Height growth curves of Marcule larch provenance

Analysis of results and discussion.

On the basis of the results obtained it was concluded that the larch provenances investigated formed a heterogenous and statistically differentiated material in respect of height, diameter (d.b.h.) and growth index.

The analysis of 20 larch provenances showed that the larches from Kłodzko and Prószków were best (reaching the highest growth results) during the entire 25-year period. These results are generally in agreement with earlier works which pointed out that larch from Sudetes shows high quality of growth (Dengler, 1942; Schober, 1958). This statement, however, should not be generalized and related to the whole larch range in that area, since the remaining provenances from Sudetes (Szczytna Śląska, Henryków and Kowary) showed much worse growth results during the consecutive study periods. Thus the larch population in Sudetes is heterogenous.

Also the larch from selected localities in St. Cross Mts. (Skarżysko, St. Cross Mts. National Park) and from their southern flanges (Moskorzewo) showed a good growth results.

This study has confirmed generally know growth results of larch from some localities in St Cross Mts. (Göhrn, 1956;Kocięcki, 1959). It has also pointed out that larch in St. Cross Mts. is not a homogenous population. The larch from Bliżyn alone confirms this statement. Its growth was much worse, and it was (especially in the first years of life) (Kulej, 1983) closer to the growth of larch from lowland localities in Poland such as: Rawa Mazowiecka, Czerniejewo, or even Grójec than to the remaining provenances from St. Cross Mts.

The growth results obtained for larches from Myślibórz, Moskorzewo and Hołubla permit to suppose the origin of their mother stands. Taking the historical data into account it may be supposed that larch localities in Myślibórz (situated outside the natural rangr of larch) originated from seeds of Sudeten origin (Bałut, 1962, 1967). Also the Sudeten origin of larch in Hołubla (former estate of Krasicki family) has been confirmed. On the other hand the larch from Moskorzewo originates most likely from St. Cross Mts. (Bałut, 1962).

Taking into account the growth characters of the larch provenances investigated and their interrelations it was concluded that when they are 5 years old we cannot forecast their further growth. Such forecast may carry an error. On the basis of the results obtained we can only suppose that at the age of about

8 years the stabilization of the position of individual provenances as regards growth takes place to a certain degree. These results are in agreement with earlier investigations in this respect (Hassemann and Schönbach, 1970).

Growth dynamics variation of larch populations investigated has also been confirmed by the height growth curves and the age of its culmination. The growth curves for individual provenances during the 25-year period (with exception of alrch from Marcule which assumed the position below the compensated curve of value $\bar{X}$-0,5S) fall within the interval ±0,5S from the compensated curve for the entire population.

All larch provenances in this experiment had reached the height growth culmination. As regards this character also a considerable differentiation among provenances may be observed. This concerns the provenances from outside of the natural range of larch in Poland (Myślibórz Północ, Pelplin, Konstancjewo-Płonne, Konstancjewo-Tomkowo), where the difference in culmination age was about 3 years, as well as the two main centers of larch natural occurrence in Poland, i.e. St. Cross Mts. and Sudetes. In the group of provenances from St. Cross Mts. this difference was small (1 year), and among the provenances from Sudetes it was as much as 6 years.

Final conclusions

1. The larch provenances from Poland tested in the experimental area in the Forest Experimental Station in Krynica are not homogenous since there is a significanta variability in basic larch growth characters at the age of 5, 8, 11, 15, 20 and 25 years.

2. The larch provenances from Kłodzko and Prószków turned out to be the best as regards the growth during the entire 25-year period. They are closely followed in this respect by the provenances from Skarżysko, Moskorzewo and St. Cross Mts. National Park.

3. The growth results obtained in Krynica for the provenances from Myślibórz, Hołubla and Moskorzewo indicate that they originate from different mother stands.

4. When 5-years old we cannot forecast a further growth of larch since such forecast may carry an error. However, on the basis of the results obtained we can conclude that when trees are about 8-years old the stabilization of the position of the individual provenances as regards growth takes place.

5. The height growth curves for individual provenances during 25-year period (with exception of the provenance from Marcule) fall within the interval ±0,5S from the compensated curve for the entire population studied.

6. All larch provenances in the experiment had reached the height growth culmination. A greatest differentiation in respect of this character occurred in case of the provenances from Sudetes.

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Growth dynamics variation of different larch provenances under the mountain conditions in Poland

Summary

The results of 25-year investigations based on measurments and statistical analysis concerning the growth dynamics variation of larch provenances from the entire area of Poland are reported in this paper (fig. 1, tab. 1). This is the first larch provenance experiment in Poland under mountain conditions of Gorce Mts. and Sądecki Beskid Mts. (experimental area in the Forest Experimental Station of Krynica).

The results obtained showed a significant variability among the provenances tested as regards the basic growth characters (height, d.b.h., growth index) at the age of 5, 8, 11, 15, 20 and 25 years (tab. 3). The larch from Kłodzko and Prószków turned out to be the best in respect of growth during the entire 25-years period. Decidedly bad were provenances from Marcule, Grójec, Rawa mazowiecka and Krościenko (tab. 4, 5).

We cannot forecast the future growth of larch when trees are 5-years old since such prognosis may carry an error. However, on the basis of the results obtained it may be concluded that when trees are about 8 years old the stabilization of the position of individual provenances as regards growth takes place (tab. 4, 6, 7).

The height growth curves for the individual provenances during the 25-years period (with exception of the provenance from Marcule) fall within the interval ±0,5S from the compensated curve for the entire population studied (fig. 3, 4). All larch provenances in the experiment had reached the height growth culmination. A greatest differentiation in respect of this character occurred in case of the provenances from Sudetes (tab. 8).

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GROWTH AND PRODUCTION OF *LARIX DECIDUA* MILL. IN SLOVAKIA

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SUMMARY

Larch (*Larix decidua* Mill.) is in Slovakia an economically important autochtonous woody plant. In forest of Slovakia its portion represents 2.22 %.

It is classified among the woody plants with good prospects for the future because of its high wood quality, many-purpose utilization especially in furniture making industry, good growth rates (volume), housing architecture. Good ecological and growth conditions found in Slovakia predestinate its increased representation.

Natural forests of Slovakia larch is usually grown in mixed stands with Norway spruce (*Picea abies* (L) Karst), fir (*Abies alba* Mill.) and beech (*Fagus sylvatica* L.) and it creates either small groups or a solitaire. Favourable allelopatical relationships of these stands support its good growth rates and volume production.

Two International provenance trials with larch established at Podbanské in 1944 (IPT I) and 1958 (IPT II) can be found in Slovakia. The former consists of larch trees from 42 provenances and the latter from 14 provenances.

The evaluation of growth and quality characters at the age of 40 years (IPT I) and at the age of 30 years (IPT II) has brought the following conclusions:

- The best height growth rate was observed with the larch from the Carpathians provenance (Slovakia, Bohemia, Moravia, Poland). Of Alpine provenances only some deserve further attention - those of the Tyrol. Also allochtonous German provenances proved a very good growth rate.

- The height, thickness and volume growth showed great differences between individual provenances, as well as between repetitions which speaks of the heterogeneity of the area but unfortunately it is being lowered with the increasing age. Highest values are permanently

obtained by home provenances Smokovec (The High Tatras) and Čierny Váh (The Low Tatras).

- Better results were obtained with the provenances of the Carpathian region than those of the Alpine region.

These results obtained in larch provenance trials add a new knowledge on suitability of particular provenances for growing larch in ecological conditions of Slovakia. It is a permanent need to extend the base of recognized larch stands, select trees, seed orchards and seed stands in Slovakia which certainly will contribute to the conservation of its most precious gene pool in Slovakia.

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Survey of data and results of measurements of height and diameter growth and volume production of larch provenances on the second International provenance surface in Podbanské at the age of 30 years

No	Provenance	State	Ecotype	Altitude above sea-level	Height growth	Diameter growth	Volume production
				m	m	cm	$m^3.ha^{-1}$
8	Semmering	Austria	Alps	1200	12,66	13,25	48,33
15	Bruneck	Italy	Alps	1200	13,19	12,97	73,57
19	Pergine	Italy	Alps	1300-1400	11,26	13,71	16,66
20	Cavedine	Italy	Alps	600-700	10,75	12,32	7,63
22	Embrun	French	Alps	1600	9,67	11,17	4,31
39	Zabřeh	Czech	Sudethian	450-500	15,84	18,11	175,03
43	Blizyn	Poland	Carpathian	320-340	15,50	17,77	194,64
51	Čierny Váh	Slovakia	Carpathian	780-830	16,31	15,93	252,61
52	Štrbské Pleso	Slovakia	Carpathian	1360-1380	15,70	15,88	205,85
53	Smokovec	Slovakia	Carpathian	1150-1250	17,60	17,01	253,43
59	Brezovička	Slovakia	Carpathian	820-840	14,67	15,63	155,87
67	Staré Hory	Slovakia	Carpathian	850	15,23	15,02	201,04
68	Liptovská Teplička	Slovakia	Carpathian	1350-1420	15,43	16,10	205,28
71	Piatra Arsa	Roumania	Carpathian	1160-1260	10,99	12,43	61,10
Average					13,91	14,80	132,52

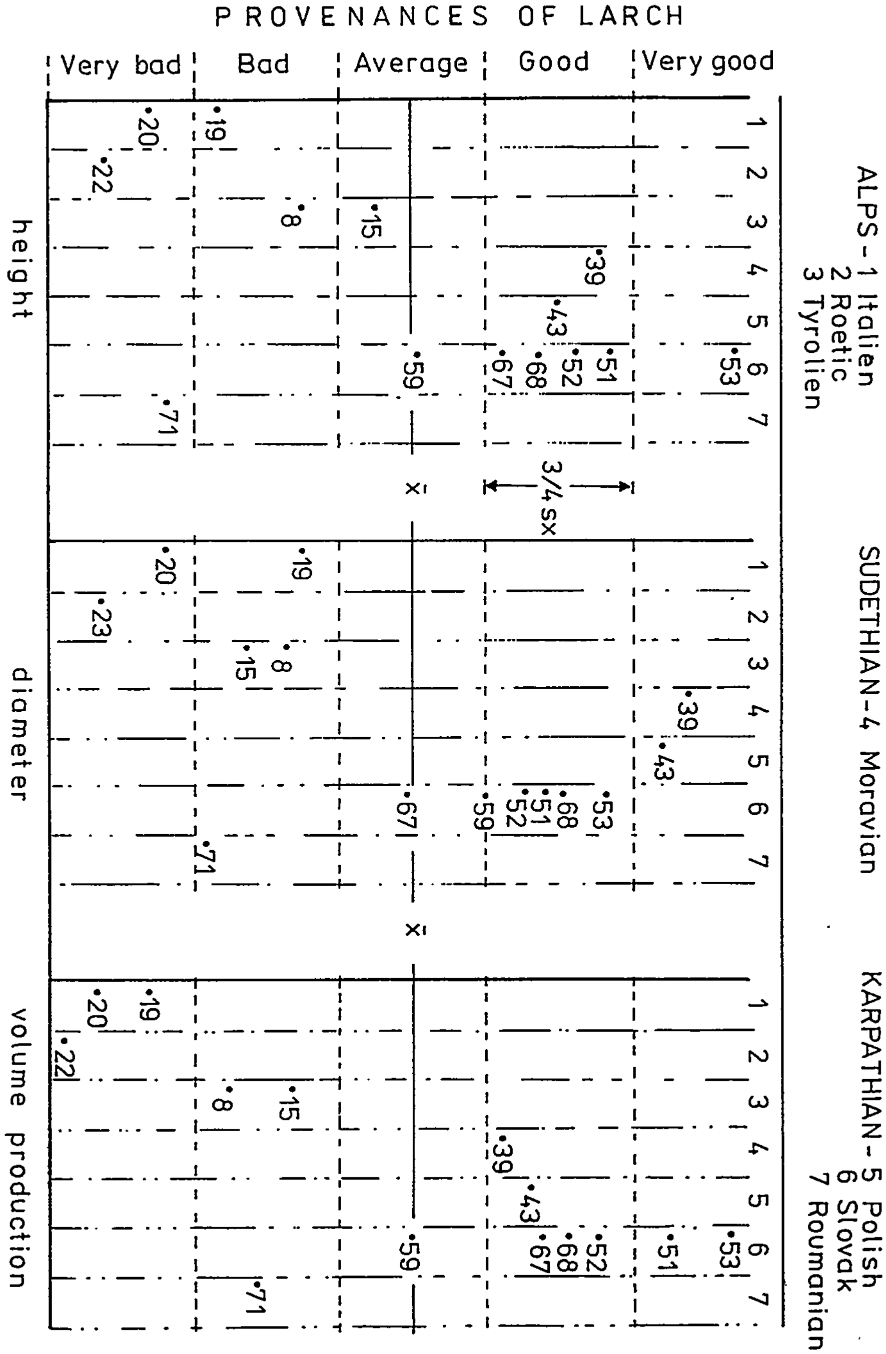

Figure 1. **Distribution of provenances of larch on the second International provenance surface Podbanské at the age of 30 years by mean height, diameter, volume production and origin in relation to 3/4 of the standard deviation.**

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The Conversion Of Evenaged Into Unevenaged Mixed Conifer Forests In Southern British Columbia.

Many of you are probably quite well-informed about the rain forest of the British Columbia coast. In contrast the interior of the province is not so well known. Once you cross the mountains of the Coast and Cascade ranges there is quite a sudden change in the vegetation as the maritime climate with over 200 days of growing period changes to a continental climate with a tremendous temperature range and varying amounts of precipitation.

The area where I practised forestry for 31 years lies in the extreme south and centre. In fact Midway, my base, was called that by the Royal Engineers who in 1859-1863 surveyed the boundary with the United States because it was roughly halfway between the Pacific coast and the crest of the Rocky Mountains. Geographically located between the better known Okanagan valley and Kootenay country the area is still known as the Boundary district. We are in the Columbia river watershed, the principal drainage system is the Kettle (formerly Colville) river and its tributaries.

Topographically Midway is at 570 m above sea level the lowest elevation. Several parallel mountain ranges lie in a roughly north-southerly direction and rise to about 2,400 m in several peaks. There also is a rolling plateau with numerous lakes and swamps in about 1,300 m elevation with extensive evenaged spruce-pine-balsam forests.

The climate is dry with a pronounced precipitation deficit during the summer, ranging from less than 250 mm annually in the most southwesterly part upwards to over 1,000 mm. Winter snowfall varies commensurately from less than 30 cm to over 200 cm. The line separating the area with precipitation deficit from that with a surplus can be drawn from the southeast to the northwest through the area and constitutes the transition from the interior drybelt to the wetbelt. The normal annual temperature range lies between -40 and +40 degrees C. The average frostfree period for sensitive crops is given as 70 days in Midway; most late spring and early fall frosts are caused by the extremely dry atmosphere leading to severe radiation loss.

During the International Hydrological Decade 1965-1974, a joint Canada/B.C. programme measured the water budget of an entire watershed in this area with a series of deep wells, stream flow recorders, and evaporimeter stations. The extreme value established was a deficit of 1,500 mm precipitation. During the growing season farmers are commonly licensed to apply at least half this amount to irrigate agricultural crops.

Most soils are highly permeable sand and gravel as they derive from glacial-fluvial outwash and terraces or from moraine till deposits. The most recent glaciation reached its southerly limit approximately 100 km to the south. In some locations the soil is enriched by the high mineral content of deteriorating basalt which occurs in a number of volcanic upthrusts through the batholith and sheet deposits. The entire area is also overlain by an aeolic veneer of fertile volcanic ash which has been dated to an eruption in the Cascade Mountains about 6,000 years ago. These soils are known for their water-holding capacity which no doubt has a beneficial effect on the growth rate and quality of commercial tree species. I believe this to be the most persuasive explanation for the absence of Larix occidentalis on the west side of the Okanagan valley where otherwise identical conditions prevail. Incidentally the contact zone is known to be extensively mineralized which has led to a number of prosperous metal mining industries.

Forests cover the entire area except the most southerly portion and south-facing slopes which represent the extreme northern limit of Merriam's Upper Sonoran Life Zone. Grassland not only is the consequence of low rainfall and humidity and of soils which are shallow to bedrock but also is the natural vegetation on the rich carbonate soil which is too alkaline to accommodate conifers.

Commercial forests are usually logged to about 1,800 m elevation but can extend higher with the upper tree limit consisting of scattered spruce, balsam, lodgepole pine, and finally Pinus albicaulis deformed to krummholz at about 2,300 m.

There is no question that both climatic and edaphic conditions promote the establishment and retention of the naturally unevenaged mixed conifer forests which the first settlers found when they arrived 150 years ago. The dominant conifer of the lowest, driest site is Pinus ponderosa which tends to form pure stands of widely spaced trees as it reaches maturity. Because of the solid ground cover of the bunch grass, Agropyron inerme, these stands are commonly known as the semi-open range of the drybelt. In the vicinity of streams and rivers including annually inundated flood plains and islands it readily and incongruously mixes with Populus trichocarpa which cannot grow where it does not reach the water table. Most of these stands have long been cleared for farmland in B.C. but many still exist in eastern Washington and parts of Idaho and Montana.

With increasing elevation P. ponderosa becomes gradually less frequent until at about 1,200 m it fades from the picture. It is replaced by an increasing presence of Douglas fir (Pseudotsuga menziesii), Western larch (Larix occidentalis), and lodgepole pine (Pinus contorta). With increased elevation temperature extremes are reduced while humidity is increased so that the mixed species forest becomes, first in the moisture receiving sites and gradually overall, an even richer mixture including Engelmann spruce (Picea engelmannii), subalpine fir (commonly called balsam, Abies lasiocarpa), Western red cedar (Thuja plicata), Idaho white pine (Pinus monticola), Western hemlock (Tsuga heterophylla), and aspen (Populus tremuloides) without losing its ability to form unevenaged, multi-level stands.

These stands have from the first days of settlement always been utilized in a very extensive, selective manner and were never clearcut. The first large-scale timber harvests occurred just before World War I during the construction of the railway with its need for large timbers for bridges and trestles and for hand-hewn ties. Soon thereafter began the mining boom which led to the construction of three large smelters. Large sawmills which had been started in the twenties folded with the onset of the worldwide depression of the thirties. It wasn't until after World War II that the forest products industry resumed on an export-oriented scale.

Because of the long distance to market all operations were strictly market-driven. I remember a stand of mixed conifers which had been logged first in 1925 for its large ponderosa pines. In 1947 all the large-diameter Douglas fir and larch were logged. In 1964 the stand was logged again as many trees had added significant increment as a result of the earlier logging. At this time lodgepole pine was still not regarded as a commercial species so when in 1985 it was attacked by bark beetles it was entirely profitable to relog the stand for a fourth time in 60 years. In another 30 years the stand can be logged again, and all the roads will still be in place.

Because of the high frequency of dry thunderstorms and the abundance of desiccated vegetation the forests in lower elevations were subject to almost regular ground fires which in the past prevented the establishment of shrubs and trees with thin, heat-sensitive bark. As long as the fires occurred frequently ponderosa pine, Douglas fir, and larch were able to survive ground fires because of their porous bark. Of course, when settlers came, they interfered with nature and put the fires out. This resulted in a gradual accumulation of highly combustible material which, when it then caught fire, would cause an extremely hot and destructive burn which no forest could survive. The result invariably was a cleared area ready to become cropland.

Even if left undisturbed after a fire but even more so if it was logged the site now became prone to severe desiccation which could lead to erosion not so much by melting snow but more likely by torrential downpours during the summer storms as well as by the constantly blowing desert winds. Commonly these sites would not regenerate with trees for a long time, usually during periods of relatively rainy summers.

Another consequence of preventing frequent fires was the gradual invasion of initially pure pine stands by Douglas fir. There is no question that Douglas fir will in many places form the next successional stage in the evolution of the drybelt forest. Where previously it did not succeed because of repeated fires, extinguishing the fires created a more receptive growth area which it quickly occupied. With it there also came an entire range of low shrubs such as Juniperus communis, Ceanothus sanguineus, Shepherdia canadensis, Symphoricarpus albus, Pachistima myrsinitis, Amelanchier alnifolia, roses, Vaccinium sp.being the most prominent. The entire aspect of the previously pure stand of widely spaced pine of all ages in a rich grassland changes to something that looks quite different.

It is important to recognize that this change is entirely the result of a sudden absence of fire. Anyone intending to perpetuate the "natural" forest cover must accommodate such effort by using fire to create and maintain the conditions for its existence. Just as naturally it goes without saying too much that from recognizing the importance of fire to actually imitating the process is going to be an arduous route. After all these years of diligently putting out every fire it will require a considerable leap of faith to embrace its benefits in a complete reversal of attitude.

There are efforts being made to use fire on a small, controllable scale in some U.S.National Forests. What they already learned is that the use of fire for site preparation in completely safe and controlled manner is very costly to conduct and still carries with it the prospect of subsequent penalties and law suits for unintended damage.

However, it should perhaps be mentioned here that in some circumstances there is an incentive to burn the duff layer under Western larch. Professor Jenkins of Utah State University has described the cause of severe seed depletion by the larva of the cone moth, Strobilomyia laricis. While in the drybelt the larvae which winter in the duff layer under the tree, are often enough destroyed by fire and so contribute to an adequate seed supply, in the wet country fires are too infrequent and allow the build-up of a large cone moth population and subsequently, insufficient seed.

Large-scale forest fires which because of the sparse population remained almost unchecked occurred until about 60 years ago. Those were the drought years of the Depression when many farms failed to produce a crop. Most fires were caused by lightning strikes but some were also caused by people. In the absence of a social security net as we know today, getting paid 25 cents per day plus three meals for maintaining a fire guard kept many men from starvation. It is not unknown that desperate men kept the fires burning even when they didn't start them. In addition an old-time rancher told me that at the time he first homesteaded in the twenties the local Indian tribes would regularly burn the forests to create and improve the big game habitat for hunting. Some of the forest cover created by these fires has now grown to be harvested after much of the fire-killed old-growth timber was still being salvage-logged thirty years after the fire and sawn into lumber.

Of the tree species which survived the fire, Douglas fir and Western larch thrived especially well from the exposure to increased light and nutrients. Both species respond well to release and add considerable increment even in advanced age. Twenty years ago it was economical to harvest the surviving residual veterans (Ueberhälter) in extensive harvests of as little as 70 m^3/ha because the yield was premium quality lumber which when carefully sawn attracted a good market return. This could only be done by competent sawyers having manual control of each saw cut, and would be impossible to achieve in a fully automated modern mill.

The most prolific species to regenerate after fire is lodgepole pine (Pinus contorta) mainly by virtue of its abundant, regular seed production, often in serotinous cones. These are tightly closed cones which require the heat of fire to open for the release of the seeds. There are areas of such dense growth that the entire crop stagnates. Several hundred thousand trees per hectare up to 3 m high can be seen frequently, and cover a large portion of the central B.C. plateau.

Most of these stands would no doubt benefit from intensive spacing and thinning but because of the high cost, this is not an option. The best thinning effect is snow loading. When the residuals mentioned above were removed the disturbance caused by felling and yarding was of considerable benefit. The uniform layer of reproduction was broken up and created edges which offered individual trees an advantage. Once this was recognized large areas have been mechanically strip-thinned with bulldozers.

Residual Douglas fir, larch, and ponderosa pine, even if they survive only long enough to produce one more seed crop, guarantee that regeneration is seldom pure lodgepole pine. The faster growth and better resistance to snow pressure especially of larch seems to favour a rapid stratification from which all species benefit. As such stands become older the natural mixture is perpetuated, and the establishment of a multi-species, unevenaged, and two- or more-layer forest is well under way. Under the best natural conditions there will follow a gradual opening up of the canopy by the occasional ground fire and the relatively short life of pine. The most likely successional species is Douglas fir, but in areas with sufficient soil moisture more shade-tolerant species such as spruce, balsam, hemlock, and cedar also become components. However, the dry climate with a high volume of light creates a condition where even the shade-intolerant species, including ponderosa pine, can be seen to germinate and grow under a canopy of parent trees. Under such conditions the conversion of evenaged into unevenaged mixed conifer forests becomes a self-fulfilling prophecy.

The prospect of creating a clearcut-free, insect and disease resistant, multi-species and market-friendly forest appealed to my company in addition to the necessity of salvaging a large volume of the lodgepole pine component which had become infested by the bark beetle, Dendroctonus ponderosae, or had already been killed by it. In order to remove the greatest possible volume of this material without exceeding the allowable regulated cut, all operations were restricted to the selective harvesting of pine only.

In the predominantly 100-130 year old stands which were most severely affected the harvest proceeded at the pace of the infestation. As many trees of other species as could be expected to remain standing were deliberately spared. In practice that meant older Douglas fir and larch which were already extending above the general canopy level and had become wind firm, but could also include same-age trees. Any spruce, balsam, or cedar was not preserved because their thin bark is sensitive to sunscald damage once exposed. Of course all trees had to be removed for road rights-of-way and landings. For several years a production level of 80 per cent lodgepole pine has been maintained and the need for costly plantations been significantly reduced.

Depending on how many of the larch were in the mixed stand to begin with and how many could be preserved, the residual stand offers a pleasing aspect of a seed-tree, shelterwood, or more or less fully stocked forest which after only a few years fills in with a vigorous young growth of mostly lodgepole pine and larch. In areas where there was an absence of designated residuals the equipment operators were instructed to avoid destroying any advanced regeneration and small-diameter understorey, and to leave lodgepole pine tops and branches with their serotinous cones scattered throughout the area to provide not only a source of seeds but also to ensure adequate shade for the seedlings. Because of the reserved growth the burning of logging slash would be restricted to the enormous heaps which have accumulated at the landings. The broadcast burning of slash was entirely restricted to areas where plantation was a foregone conclusion.

Of course, there are other ways to create conditions which without being as hard to control as fire are equally conducive to prepare a seedbed for natural regeneration or a site for plantation. Mechanical site preparation can be very successful, is effective, less hazardous but is costly as well as it is high in energy demand. Therefore, it has generally been restricted to areas where during logging operations there had been more than about half a metre of snow. Other areas usually have sufficient disturbance of the surface to expose the mineral soil needed for germination.

The equipment which our contractors preferred for site preparation was and likely still is the brush rake mounted in front of a tractor in place of the dozer blade, and used extensively for land clearing. Many other types of equipment were and are being tried and discarded. All scarifiers that have to be pulled present problems when in our terrain the operator had to back up or manoeuver around protected growth. The brush rake, besides easily transported and attached to equipment already on the site, is relatively inexpensive, trouble-proof, and can be adjusted to the conditions of the site as well as be made to fit different equipment. Its manoeuverability is unmatched which is also the cause of its major disadvantage. We discovered that most operators tend to do too thorough a job as if clearing land for agriculture. Consequently they had to be trained to be less efficient. Experience shows that an operator who on average covers less than a hectare per hour creates conditions which more likely than not result in too dense restocking.

Areas on which regeneration does not meet precise standards set by the Chief Forester of B.C. are classified as Not Sufficiently Restocked (NSR) which can mean not only the total or partial absence of any young growth but also of young growth which is not listed as the preferred species on the site, having defects or unacceptable qualities, or growing unevenly distributed or too dense overall. It doesn't matter that this was how the original stand became established, we just can't have non-conforming young growth in today's tightly regulated and managed forests. So a lot of money is being spent in trying to correct nature.

The most glaring example in my experience was the case where natural regeneration at first was slow in coming and was ordered to be supplemented by costly fill-in planting. Then natural regeneration really came in profusion and it became necessary to perform costly spacing work to correct the density. Invariably in nearly all these cases the naturals look so much better than the planted seedlings so the trees being removed were the planted nursery stock. The directives requiring this expensive procedure became known as "Political Silviculture".

Older regeneration in need of spacing can often be utilized if there is a market for the product. In our area there always seems to be a demand by the ranching and fruit growing industry for fence posts and rails, tree props, and grape stakes for which we had large stands of the right species and size located reasonably close to our well-maintained road network. We succeeded in contracting the spacing of some stands in a rare arrangement of mutual benefit. The contractor had a market for the material and we wanted the spacing done in perfect balance of expense and return. We came to call it "serendipity spacing", and reliable contractors, once they had learned and understood our objective, were able to perform the work with a minimum of control and supervision. Most were local residents looking for repeated contracts so it was to their advantage to do a good job.

In the conversion from evenaged to unevenaged mixed species stands a major obstacle develops in the calculation of growth and the anticipated yield to determine the long- range sustained yield. Forests have traditionally been treated as evenaged, single-species entities for which it was relatively easy to determine the point of culmination at which they should be harvested. Yield tables have been constructed only for these simple stands. To make it even easier a province-wide general rule applies which sets minimum harvesting ages for all commercial tree species at 60 years for broadleaved trees, 80 years for lodgepole pine, and 120 years for all other conifers.

The incentive to convert to unevenaged mixed species forest, as much as it was applauded as the more natural treatment it was, always and for many years has faltered at the inability or reluctance to abandon age as the controlling factor. How insignificant the age of individual trees really is in such a forest can be demonstrated by just one example from natural forest which has never been logged. We discovered that the oldest components were larch of approximately 230 years with diameters ranging from 40 to 100 cm. On the other extreme there were many Douglas fir with a very uniform diameter of about 35 cm which ranged in age from 70 to 230 years. This complexity has very much discouraged the construction of yield tables which would have to be based on volume or diameter to be applicable for the regulation of an allowable cut that is still being expressed by volume/age curves.

The first tentative steps to establish growth and yield tables in unevenaged forests destined to be harvested selectively have been taken with the establishment of permanent sample plots (PSP) in recently harvested stands starting about 40 years ago. These samples are designed to be remeasured every ten years. Our company participated in the project by establishing fifty such plots in representative stands but since any application of the results would have to come under provincial jurisdiction it got bogged down in an argument between the research and inventory divisions of the B.C. Forest Service.

However, we do already know that all species respond vigorously to release after a partial cut regardless of age, that new growth becomes established quickly and mostly of the desired species mix, and that a considerable merchantable volume can be removed economically at 25 to 35 year intervals. The mean annual increment (MAI) in most of these stands has been established as between 2 and 4 fm/ha.

The principal reason why yield tables have been slow in being constructed remains the simple fact that the area of B.C. which would benefit from such is insignificantly small by comparison, and so much forest is still out there that has to be harvested for the first time. There have always been so many other more pressing exigencies.

Another consideration when operating in these stands is the sudden realization that our entire workforce must be retrained to perform selective harvesting with due respect for the reserved trees and young growth. With the type of equipment now in use and with the much improved general education level I am happy to report that the task is feasible. My experience has been that our fallers and equipment operators were as interested as we were to do a good job in protecting the residual growth. It soon became common practice to trust their judgment which trees to select for removal in a procedure commonly known as "faller selection". Of course there have been mistakes and bad performance which points to the need for continuous supervision and control. On the other hand we have gained a more conscientious work force than we ever had. Workers think about their work and often suggest improvements. In addition we have learned to be flexible and not to rely on rigid standards and stubborn insistence.

Nature is capable of correcting many mistakes and rough handling. One of our logging contractors was convinced that the difference between a good job and a bad job logging was no longer than two years. To that must be added the fact that the government inspectors who inspect the work are far from unanimous in their opinion of what is and what is not acceptable practice. Obvious are only the most careless, deliberate, and otherwise flagrant instances of transgression. I have often returned to scenes of the most damaging practices in the past and marvelled at the ability of nature to heal so quickly once it is left alone.

In conclusion I reiterate what to me appear to be the most basic requirements for successful conversion to an unevenaged, single-tree selection management. We should have a mixture of tolerant, preferably pioneer species, an abundance of light for germination and early growth, and frequent or at least regular disturbance either by repeated ground fires or selective logging. It is debatable whether regular grazing by domestic livestock as it is practised here also adds to the readiness for conversion but should perhaps not be overlooked. In the best case it certainly does not interfere or cause damage as it perpetuates traditional rights and practices predating other forms of utilization.

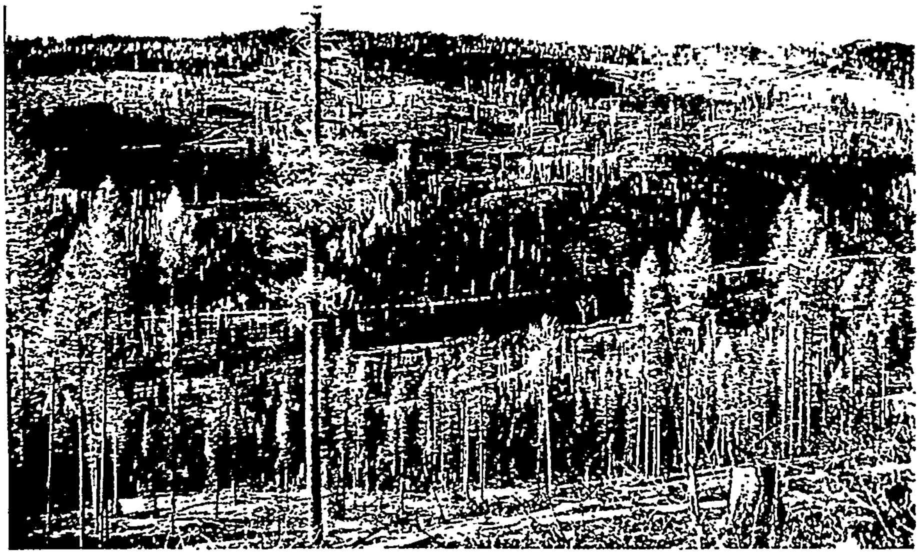
I am sufficiently familiar with a considerable portion of the natural range of <u>Larix occidentalis</u> to be convinced that my experience is not unique and can be applied over a wide area of southeastern British Columbia, northeastern Washington, and northern Idaho and Montana.

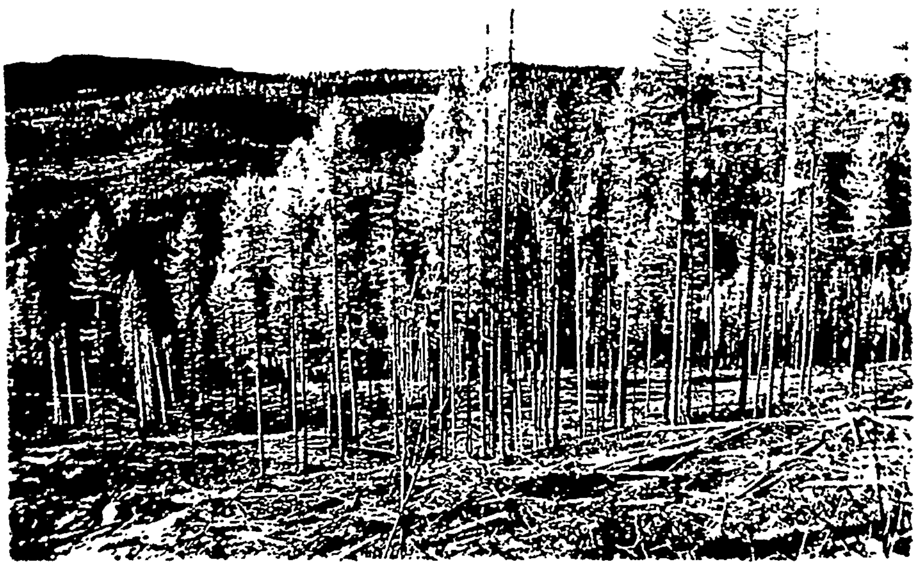
Abstract.

A detailed description of the conditions and history leading to the establishment and continuity of all-aged mixed coniferous forests in the montane south central region of British Columbia, Canada. Also described are the attempts by one forest products company to perpetuate and proportionally increase this type of forest cover through the selective removal necessitated by bark beetle depredation of the component, Pinus contorta. The report concludes with a description of and recommendations for the post-harvest management employing treatments which imitate natural conditions leading to a gradual and lasting conversion of natural multi-species stands into unevenaged or all-aged stands of mixed conifers which are conducive to single tree or group selection harvests at more or less regular intervals.

TABLE: Annual Production and Activities,
Pope & Talbot Ltd., Midway, B.C.

Description	1988	1989	1990
Volume Harvested, m^3	840,422	715,480	866,356
Percent Beetle Killed Pine	84	80	87
Volume Purchased, m^3	219,473	245,905	283,425
Mechanical Site Treatment, ha	1,700	2,140	1,696
Broadcast Slash Burned, ha	750	320	546
Regeneration Surveys, ha	4,139	5,744	7,265
Found Sufficiently Restocked, %	61	73	72
Area Planted, ha	1,031	1,420	2,939
Seedlings Planted, Thousands	1,500	1,800	3,119
Brushing And Weeding, ha	818	339	139
Juvenile Spacing, ha	60	386	170





s. 1-3:
residual stand
er removal of the
k beetle infested
killed lodgepole
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nsists of
dominantly
tern larch,
ıglas fir,
casionally spruce,
.sam, and cedar,
l small groves of
pen. The
eckered aspect of
e stands indicates
e uneven
stribution and
ried intensity of
ghtning-caused
ldfires. Although
tally unintended
leaves a pleasing
d unobtrusive
age because
raight lines and
earcuts are
sent.

Figs. 4,5:
Although the soils are coarse and highly permeable, the lack of precipitation and long intervals between rains are the reason for the general absence of erosion even on moderate slopes. Another factor contributing to soil stability is the carbonate component of the often aeolic basalt-derived deposits prone to cementation. Another stabilizing factor is the seeding with forage grasses for both ungulates and domestic livestock on skid trails and landings immediately after logging.

Fig. 6: Some residual Douglas fir and larch are subject to blowdown and have to be salvaged but the experience to date has been of only minor losses. Often blowdown occurs after the dispersal of at least one seed crop so that regeneration is assured.

Figs. 7,8:
Logged areas regenerating naturally a few years after logging.

Below, figs. 9,10:
The ultimate objective is the creation of completely unevenaged mixed conifer stands similar to these which have been selectively logged as often as four times since 1925.

GROWING LARCH IN THE RUSSIAN NORTH AN OUTLINE

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The first larch cultures in Russia were established more than 200 years ago. The Lindulovskaya Forest established by Fokel in 1738 in order to supply shipyards with wood is the oldest of them. This precursor of the Russian larch plantations originates from seeds collected in the Arkhangelsk Province. Nearly one hundred years later (1832), the first nursery to grow large amounts of larch seedlings was established in the Cherdynsk District of the Perm Province. This was due to increasing demands to develop a national navy. During the period of 1917 - 1966, in total some 147 thousands hectars have been covered with larch cultures in Russia.

In the North, the first larch cultures were established in Karelia in the middle of XIX-th century. However, a major effort to develop larger areas of the larch cultures took place there in the 50-ties, and during 1952 - 1956 the area of larch cultures reached some 2 220 hectares. Most of these cultures (80 - 90 percent) were established by direct seeding. Larch in Karelian cultures grows relatively fast, *e.g.* in the Sortovala Forest District reaching some 10 m height after 20 years, and 18 -20 m height after 70 years. Karelian researchers (Gavrilenko, 1960, Lantratova, 1957, Sboeva 1961) recommend growing larch in pure, not so dense (800 - 1000 seed beds/hectare) cultures. They should be established on well drained sandy-clayey soils.

On Kola Peninsula of the Murmansk Province, the interest for growing larch begun in the 30-ties. During 1952 - 1964, the larch seeds have been sown on the area of 1200 hectares. In total after 40 years, the area of cultures of introduced larch species (*Larix gmelini, L. sibirica, L. cajandrii* and *L. czekanowskii*) in the Murmansk Province increased up to more than 3 thousands hectares. The seed consumption in these cultures ranged from 1.5 to 3.5 kg/hectare and the number of seed beds varied from 2 to 10 thousands/hectare. Clear-cut areas covered with spiked willowherb (*Chamaenerion angustifolium*) were found to be the best sites for growing larch in the Murmansk Province. Nikonov and Sizov (1987) who studied adaptability of larch seedlings to new conditions, found quite a strong correlation between their survival capacity and the content of some chemical substances in seeds and needles. The ash and microelements content in seeds and needles, the silicon, phosphorus and calcium content in seeds and the sulphur content in needles, seem to be the best indicators of the above adaptability.

In the Arkhangelsk Province growing larch in cultures begun some time during the second half of XIX century. The first trials to grow larch took place on Solovetskiye Islands, however very first experimental cultures of this species were established by S.V. Alekseev in 1935 in the Obozerskaya Experiment Station. After 26 years their average height was about 6.5 m. In a larger scale, establishing of the larch cultures in the Arkhangelsk Province started in 1948. After 25 years the total area of these cultures reached 1183 hectares, *i.e.* about 1 percent of all cultures of coniferous tree species established in this period in the Province, only.

Generally, in this time the majority of larch cultures (*ca* 90 percent) were also in the Arkhangelsk Province established by means of sowing. Usually, the soil preparation included removal of the litter - either followed or not by crumbling of the soil - and mixing up the humus layer with the mineral soil horizons. Seeds were sown in the seed beds of size up to 1 m^2.

From 1979 the importance of direct sowing decreases and the larch cultures are established mainly by means of planting the nursery seedlings. Up to 1990, the total area of new larch cultures in the Province reached 1046 hectares, of which only 116 hectares originated from sowing. The survival of planted 3-years old larch seedlings on individual cultures varied from 42 to 93 percent. The highest mortality rate was observed in the cultures established on former clear-cut areas that were predominantly covered with hair moss (*Polytrichum sp.*) and hair grass (*Deschampsia sp.*). On such sites the survival of 2 - 4-years old seedlings varied from 29 to 89 percent. The competition from sod grasses such as bushgrass and small-reed (*Calamagrostis sp.*) or hair grass (*Deschampsia sp.*), the excessive soil humidity during planting time, the frost-heaving, and the sunscald (sunburn) were identified among the most important causes of the larch seedlings' mortality. Their survival also depended on the soil preparation technology and on the accuracy of planting.

Interspecies trials of larch were established in the Arkhangelsk Province in form of small, experimental cultures. According to Semenov (1989), among those established on Kanin Peninsula the plantations originating from seeds of Siberian larch (*Larix sukaczewii*) - collected in the Arkhangelsk and Vologda Provinces - were more successful than were the plantations of other larch species (*L. gmelini, L. kurilensis, L. cajandrii*). Among 10-years old plantations established in the Plesetsk District and including five ecotypes (provenances?) of the Siberian larch (*Larix sukaczewii*) and five ecotypes of the Far East larch species (*L. maritima, L. gmelini, L. amurensis* and *L. kurilensis*), the best growth and the highest resistance expressed Siberian larch originating from the middle taiga sub-zone of the Ekaterinburg and Irkutsk Provinces (Nakvasina, 1989, Popov *et al.*, 1988).

In Komi, the first cultures of larch were established in 1949. During the first three years the larch seeds have been sown on an area of 5.1 hectares. In the years 1957 - 1977 the total area of larch cultures increased up to 618 hectares, of which some 60 percent were established by means of planting. During the next period, *i.e.* 1978 - 1990, the cultures (mainly planted) were established on an area of 2110 hectares. However, the survival of 5-years old seedlings in these cultures did not exceed some 10 - 30 percent.

The largest experience in growing larch in the Russian North exists in the Vologda Province. The cultures occurring there originate mainly from seeds of Siberian larch (*Larix sibirica*) collected in the Krasnoyarsk and Tyumen' Provinces. Before 1958, the total area of these cultures did not exceed 163 hectares, while up to 1962 it increased with additional 816 hectares, and up to 1970 with subsequent 419 hectares. Some 80 percent of these cultures were established by means of direct seeding. In many forest districts affected by forest fires took place sowing from aeroplanes, *e.g.* in the Vokhnogorsk Forest District some 250 hectares of the former fire-razed areas were regenerated in this way. This measure resulted in obtaining a relatively dense (density 0.7) mixed stand, which species composition was as follows: 3-4 larch, 4 birch and 2 aspen.

Other example of the applicability of such a regeneration method is known from the Totemskii Forest District, where in 1941 some 1000 hectares of the former fire-razed area became regenerated by means of aerial sowing. On the area of 900 hectares, the mixture of seeds including larch, pine and spruce was used, while another 100 hectares were regenerated with larch seeds exclusively. In the latter case, after 12 years the larch share in the culture was about 24 percent (1260 trees/hectare). According to Iroshnikov (1962) such a share is quite satisfactory to form - after some thinning measures - a pure larch tree-stand.

Another interesting experiment took place in the Chernovetskii Forest District, where in 1938 1-year old larch seedlings were planted on 5 hectares of the 4-years old fire-razed area. The seedlings were planted on podzol clayey soil in spacing 1 x 2 m, that gave some 500 seedlings/hectare at the planting time-point. Despite larch, also seedlings of spruce and other tree species were planted. After 38 years, in the mixed tree-stand the larch grew better than spruce, but worse than naturally regenerated birch did (Ipatov, 1977).

Cultures originated from the larch seeds collected in the Russian North were very early established also in other regions of the European Russia, in Ukraine and in Belarus'. Also in other countries, *e.g.* Estonia, Sweden, Great Britain, Iceland, the cultures of Siberian larch seem to be of high interest. In Finland, the first larch cultures were established in the 40-ties of the previous century, and larch is considered to be the most promising among all tree species introduced to this country (Tuimala, 1993).

Thanks to the up to date experience in growing larch in the Russian North, some directives for future routines may be formulated. First of all, the larch cultures should be established on large, concentrated areas. The purpose with such a concentration is to enable the successful development of ground vegetation, microflora and mezofauna as well as to start the soil processes that are specific for both the local environment and the pure larch forest. In the Russian North, the most promising for establishment of high productive, artificial, larch dominated tree-stands are the sites with shallow located limestock bedrock, *i.e.* sites on which also natural larch stands occured in the past (Kashin & Kozobrodov, 1973).

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Systematics and differentiation in the genus Larix in Eurasia

Proposal for an international research project

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Summary

Larch is a major component of the boreal and alpine coniferous forests. The timber of larch has historically been of great economic value because of its resistance to decay. In the future the natural resistance of wood to decaying fungi will be of great economic and environmental value because of the concern involved in using artificial impregnation with copper, chromium, arsenic or other poisonous compounds. Larch of different species, are therefore of growing interest for forestry. The larches of Russia are of specific interest because of the huge area of distribution, great genetic variation and the good stem quality.

The genetic structure and the polymorphism of Russian larch species have been studied only to a limited extent and not compared to European larch. Nor has the genetic adaptation of Russian larch species of different origins been systematically tested in western Europe.

The proposed project has the following three objectives:

1. Phytogeographical analysis and analysis of the genetic structure and polymorphism within and between populations, ecotypes and species of the genus *Larix* in Russia and Europe. Seed of larch from different areas of Russia and central Europe will be used for this study.

2. Seed collection of larch from selected stands between Kamchatka and the western Alps to make possible practical breeding, studies on genotype-habitat interaction in future field trials in Scandinavia and western Europe.

3. Description of stand structure and habitat of the northern Siberian taiga. Larch is dominating in the 16 selected regions for seed collection in Russia but also other conifers will be considered in this investigation.

Current state of art

A major part of the boreal forest of Eurasia consists of larch. Larch is also an important component of the mountain forest of central and eastern Europe. Since the middle of the 18th century larch was introduced and planted in northern and western Europe (Hagman 1987, Martinsson 1995, Schotte 1917, Snorrason & Blöndal 1990).

Research plots of Siberian larch already existing in Finland, Iceland and Sweden indicate that the potential for growth and ecologic adaptation of larch is great (Martinsson 1992, 1995, Vuokila et al. 1983). Considering the wood quality and the stem straightness, the larches native to Russia are superior to larches of most other areas. Efforts to introduce more breeding material of Siberian larch species should be of great benefit.

The international research on provenances, genetics and breeding of larch has been concentrated on European larch (*L. decidua*) and Japanese larch (*Larix kaempferi* Carr.) (Wiesgerber 1992, Toda & Mikami 1976). However, the largest geographical distribution and the largest concentration of larch is to be found in Russia. The forest area of Russia is covered by larch to 38 % (Milyutin 1992, Timofeef 1961). In the former Soviet Union larch has been studied mainly in the southern regions while the northern taiga is more or less unknown. Species differentiation and species characteristics, stand structure and basic ecology of larch forests of northern Siberia is not studied.

The introduced seed sources of Siberian larch in Scandinavia, Finland and Iceland has a narrow genetic origin (Hagman 1987, Martinsson 1992, Snorrason 1987). With some few exceptions the introduced material originates from the area of Archangelsk or the southern part of the Ural mountains. Peripheral populations (e.g. Archangelsk region) may harbour less genetic variation than "central" populations of *L. sibirica* or *L. gmelini* in eastern Siberia, closer to the putative Pleistocene refugia of these species, according to Frenzel (1968). Hence the eastern populations may contain more variable and valuable breeding material. The proposed project could hence be of great benefit to the work on the introduction and tree improvement of larch in western Europe, especially in areas where the climatic adaptation is of major importance. A representative collection of breeding material from the wide natural distribution of Siberian larches has never been available for international forest research.

The aim of the project is to monitor the genetic variation of the genus *Larix* along geographic transects within a range between Kamchatka and the Alps. Analysis of the genetic structure and the polymorphism of larch in Eurasia can be done on seed or seedlings. Seed or seedlings can be used for analysis of allozymes or DNA markers.

The seed collection will also make possible progeny test and practical field trials in the future. The access to the seed sources has been the main obstacle for this kind of practical field experiments in the past.

The northern part of the taiga has not been investigated and described by Russian scientists earlier. The third objective of the project is to give a detailed description of the taiga i 16 different regions (fig 1) where the seed collection will take place. The Alpine larch forests of central Europe will be described in a similar way.

Description of the proposed work

Seed collection, area and amount

Russia

Botanically the distribution of larch forests of the Russian Federation is subdivided in 3 main areas, *Larix sukaczewii* in the west, *L. sibirica* in the central and *L. gmelinii* in the east. In addition to these 3 species, 4 or 5 more species, closely related to *L gmelinii*, are identified in the central or eastern Siberia. These larch species are: *L. cajanderii, L checkanovski, L. maritima, L gmelinii* var. *olgensis* and *L. gmelinii* var. *kurilensis*. All larch species mentioned are of practical and scientific interest. This seed collection should represent all larch species mentioned and a geographic area, where the climate, within reasonable limits, reminds of the climate in Europe. Special attention should be put to areas not represented in earlier seed collections.

Larch seed should be collected from 16 regions described in table 1 and indicated on figure 1. Within each region 3 stands of larch suitable for seed collection should be identified. Selection criteria for the stands should be: Mixed or pure stand of natural larch growth of good timber quality and at least covering an area of 1 hectare. Areas where larch is rare should be avoided. Within a region the three stands should be selected at different altitudes (if possible) or growing under different site conditions. The stands should be identified by geographic positions (latitude, longitude and altitude) and indicated on a local map.

Europe

Larch seed will be collected from 5 regions: Western, central and eastern Alps, Slovakia and Poland. Within regions 3 stands should be selected and trees sampled for seed collection in a similar way as in Russia.

Depending on seed quality, the minimum collected amount of seed should be 0,5 kg per stand and 25 g per tree. The seed should be collection on single tree basis from at least 20 individual trees from each of the 3 stands of the 21 regions, i e seed from at least 1260 trees or 60 trees per region. The seed lots of individual trees will be kept separate from each other. Record of the trees collected from, i e tree height, dbh and stem quality should be clearly recorded.

Stand structure and habitat

Data on stand structure, tree species and tree size, growth rate, timber quality and macro characteristics of cones, bark and branches will be collected in all 63 selected stands. Collection of data on ground vegetation will be done in 2x2 m^2 square plots within each of the stands. There will be 20 such plots in each stand. Soil texture, topography, permafrost and water-regime will also be recorded.

Biochemical studies on the genetic variation

DNA and isozyme markers will be utilized to study the genetic variation. In addition, pilot studies will be performed by applying PCR-based methods which allow a monitoring via co-dominant markers.

Genetic parameters to be studied will be heterozygosity, genetic multiplicity, diversity, differentiation, adaptive potentials and genetic differentiation among populations.

The results of the genetic monitoring can be expected to contribute efficiently to the description of geographic variation and the mode of adaptation and survival of larch populations under extreme environmental conditions.

A detailed research plan and applications for economic support of this project has been delivered to the European Union, FAIR programme and signed by scientists at The Swedish University of Agrucultural Sciences, The Ludwig Maximilian University in Munich and The Icland Forest Reserach Institute.

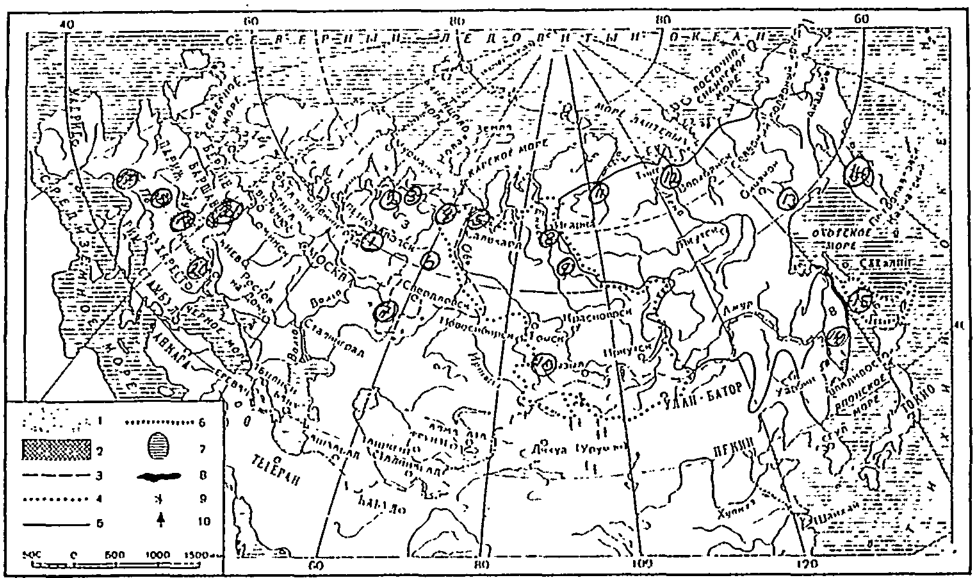

Figure 1. Seed collection regions for larch in Eurasia.

Table 1. Seed collection regions in Russia and Europe

Region N:o	Locality
Larix sukaczewii	
1.	Ivanovo. The Unza and Kostroma river valleys. The SW border area of S-larch.
2.	Shenkursk. The northern part of the Dvina water drainage, including Onega and Pinega river valleys. The NW border area of S-larch.
3.	Mesen. Low land, northern Mesen river valley.
4.	Petchora. Petchora river valley, close to tundra timber line and the arctic circle.
5.	Salschard. Northern Ural. The northernmost part of the Ural mountains. High-intermediate altitude and introgression zone to *L. sibirica*.
6.	Serov. Central Ural. Niznij Tagil-Perm-Serov. High-intermediate altitude.
7.	Ufa. Southern Ural. Ekaterinburg-Magnitogorsk-Ufa. High-intermediate altitude.
Larix sibirica	
8.	Norilsk.The northernmost part of Jenisej river valley, close to tundra timber line, north of the arctic circle.
9.	Bogucany. Angara river valley.
10	Novokuznetck. (This region could eventually be excluded). The northern part of Altai mountains. The upper drainage of Ob and Jenisej rivers.
Larix gmelinii	
11.	Chatanga. The northern border of *Larix gmelinii* in the Moijero and Kotuj river valleys.
12.	Zhigansk. The lower Lena river valley, the western part of the Verchojansk mountain range.
13.	Magadan. Ochotsk-Magadan coastal region, Lat 60.
14.	Chabarovsk. The lower Amur river valley, coastal and interior species.
15.	Sachalin.Interior and coastal provenances of *L. gmelinii* var. *kurilensis*.
16.	Kamchatka. Interior and coastal provenances of *L. gmelinii*.
Larix decidua	
17.	Western Alps, France
18.	Central Alps, Switzerland
19.	Eastern Alps, Austria
20.	Tatra Mountains, Slovakia
21.	Krakow-Kielce, Poland

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PARENTAL PARTNERS' EFFECTS ON PROGENIES CHARACTERISTICS ON HYBRIDIZATION WITHIN THE LARIX GENUS

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SUMMARY

Larch progenies of maternal clone No. 52-4-11 (*Larix decidua* Mill.) combined with the series of paternal clones of the same species and further of the *Larix leptolepis* Gord. and *L. gmelini* (Rupr.) Ledeb. species were evaluated on three research plots with larch (*Larix* sp.). Growth in height and thickness as well as stem forming were monitored at the age of 11 and 22 years. There was found out a significant share of variance falling on the action of mother, hence the existence of extra-nuclear heredity can be anticipated, particularly in interspecific hybrids. Comparing with the control in interspecific hybrids mostly luxuriant growth is displayed. On one of the studied plots there was found out the assumed growth depression in the quantitative characters of progenies originated from self-pollination. Some results of the research can be used as an auxiliary criterion in the selection of progenies and trees within the progenies for the establishment of seed orchards to produce hybrid seed of F2 generation.

Keywords: *Larix*, interspecific hybrids, progenies, parental effects.

INTRODUCTION

There have been used some prospective methods of larch breeding up to now, as one of the most promising procedures it seems to be the interspecific cross breeding within the *Larix* genus (Kiellander, 1958, Schönbach, 1967, Langner, 1971, and others). This breeding procedure is therefore in the focus of interest at present (Kleinschmit, 1988, Šindel á ř , 1988, Š i n d e l á ř , F r ý d l , 1991). Nowadays a number of both theoretical and practical issues exists still which should be solved with relation to the production and use of hybrid reproduction material. Those include inter alia the selection of suitable clones for hybridization work (combining ability), judgment of the effects of maternal and paternal clones in cross breeding, problem of the heterosis growth of hybrids and causes of it, changes of hybrid vigour in place and time (S c a m o n i , 1977, R e c k , 1977, and others. The main goal of presented paper is to contribute to the explanation of some of these questions mentioned.

O B J E C T O F W O R K

There are some results connected with the observation of three research plots established in 1969 and 1970. As for the object of this work, it is especially:

a) To judge the effect of different partners, donors of pollen, on the progenies´ growth in height and thickness as well as their stem forming. The progenies of the maternal clone No. 52-4-11 originated from open pollination were chosen as a reference criterion.

b) To estimate the share of maternal clone (maternal effect) in the variability of the progenies studied.

c) To judge to what extent the anticipated "inbreeding" depression is expressed in the progeny coming from autogamy.

d) To test and judge hybrid combinations on the research plots from the aspect of their prospective use in hybrid seed orchards.

E X P E R I M E N T A L M E T H O D S A N D M A T E R I A L

Research plots No. 14, 32 and 38 have been established in 1969 and 1970 with the reproduction material obtained within the hybridization programme which was effected in the spring of 1967 to a great extent at the Šternberk seed orchard near Olomouc. In connection with this a considerable amount of seed was harvested from the controlled cross breeding and also the material from open pollination for the purposes of comparison.

On the research plots mentioned above 18 combinations have been planted in total and in all of them the Sudeten larch (clone No. 52-4-11) behaves as a maternal clone. Out of the represented combinations five fall on the progenies of European larch (*Larix decidua* Mill.) from controlled crossing, three on the progenies of clone No. 52-4-11 from open pollination, nine on the progenies of *Larix decidua* x *L. leptolepis* Gord. and one combination consists of the progeny of *Larix decidua* x *L. gmelini* (Rupr.) Rupr. Brief characteristics of the research plots are mentioned in the Table 3 and methodic principles of the establishment of individual research plots are visible in the Table 4. All the research plots were measured and evaluated by a uniform method at the age of 11 and 22 years. In all the plots the total height and breast-height diameter were measured. Stem forming (straightness) was classified by ocular estimation according to the following four-stage scale: 1 - entirely straight stem, 2 - slightly unilaterally curved stem, 3 - more curved stem, 4 - crooked stem. The basic mathematic - statistical characteristics have been computed for qualitative characters and spectra of category distribution for stem forming. Variability was studied by means of variance analysis according to the model:

$$y_{ij} = \mu + p_i + o_j + e_{ij}$$

in which y_{ij} is the value of the i-th progeny in the j-th repetition, μ represents the trial average, p_i is the effect of the i-th progeny, o_j is the effect of the j-th repetition, e_{ij} represents the experimental error of the trial. The relations have been analyzed by the computation of correlation coefficients according to the rank (M y s l i v e c , 1957).

R E S U L T S

For the purposes of general orientation in the reliability of trial it is necessary to state that on research plot No. 14 (Administration of Trial Forest Areas of the Forestry and Game Management Research Institute at Jíloviště) there have been measured and evaluated 515 larch trees in total at the age of 11 years and 340 larch trees at the age of 22 years. As far as plot No. 32 (the Tábor Forest Enterprise, former Bechyně Forest Enterprise) is concerned at the ages mentioned there have been registered the numbers of 270 and 199 trees respectively, and 519 and 284 trees respectively on plot No. 38 (the Pelhřimov Forest

Enterprise, former Kamenice nad Lipou Forest Enterprise). Mortality was comparatively low on all the plots. The further reduction is resulted from the tending intervention effected in 1983 and 1984. The number of trees on research plots is therefore comparatively small, which is logically reflected in the reliability of trial.

Height Growth

The height growth of larch progenies till the age of 11 and 22 years is satisfactory and the averages computed for the individual research plots fit in with the height range for the 1st yield class of European larch, for the moderate tending method (Schober, 1975). The averages on plot No. 14 even exceed the upper 1st yield class limit in a significant manner. This fact is also documented inter alia by the average heights of certain progenies which reach the values about 17 m at the age of 22 years. On the plots No. 14 and 38 the highest values for individual trees approach 19 m.

It follows from the results of variance analysis that on the research plots the differences in height growth are in the majority of cases statistically insignificant. Only in two cases at the age of 22 years, the differences in the averages of progenies were found to be statistically significant. This can be explained by a possible high levelling effect of maternal clone on the variability of progenies. Another factor, which can have an influence on the facts mentioned, it is a considerable residual variance which is inter alia the result of a less precision of trials (small plots, small numbers of trees on the plots). The repeatability (heritability) determined on the research plots is low.

The advance in the height of interspecific hybrids in comparison with the progenies from open pollination could be foreseen from the theoretical assumptions. This theoretical assumption was proved only on the research plots No. 32 and 38, particularly at the age of 22 years.

Growth depression could be theoretically assumed in the progeny No. 75 (clone No. 52-4-11) coming from open pollination. This progeny is represented only on the plots No. 14 and 32. The hypothesis was proved on plot No. 32 while the averages of the mentioned progeny on plot No. 14 did not differ from the average of the trial.

The fastest growth have been determined at the age of 22 years in the progenies No. 85, 81/1 and 89. These progenies are mostly *interspecific* hybrid *combinations*. On plot No. 14 it is also the progeny No. 91, i.e. European larch originating from open pollination, which excels in a very fast growth.

It follows from the computation of correlation coefficients according to the rank (values r = 0,64, 0,71, 0,77) that on all the plots the rank of progenies, as to the height growth during the period from 11 to 22 years, does not statistically change, (correlation coefficients are positive and statistically significant).

The average height increment of progenies at the age of 11 years has already reliably indicated the trend of the further growth in future.

G r o w t h   i n   T h i c k n e s s

In comparison with the values of yield tables, the growth in thickness, characterized with breast-height diameters, exceeds the average and data for the 1st yield class on all the research plots. The advance over the yield tables is extraordinary conspicuous on plot No. 14. This might be influenced between others by the fact, that the planting density is somewhat lower than assumed in the yield tables, except for the research plot No. 32.

Similarly to the height growth, the analysis of variance as regards the breast-height diameter, also proved that the differences in the averages of progenies are statistically significant in certain cases only. The possible causes of this phenomenon were mentioned in the foregoing chapter related to the height growth. Out of six studied cases, in four of them repeatability (heritability) is low.

The conspicuous advance of the progenies of interspecific hybrids in comparison with those coming from open pollination could be stated only on the plots No. 32 and 38, at the age of both 11 and 22 years, similarly to the average heights. On plot No. 14 the average breast-height diameter computed for interspecific hybrids approaches the control.

Growth depression theoretically assumed in the growth in thickness of the European larch progenies coming from self-pollination has been proved on the research plot No. 32. Compared with the assumption, this progeny on the research plot No. 14 overtakes the control by 5% at the age of both 11 and 22 years. The difference is not statistically significant, however.

As regards the breast-height diameter, the fastest increments are found in the progenies No. 80, 81/1, 86 and 88 on the research plots No. 32 and 38. In all the cases this concerns the interspecific hybrids of European larch and Japanese larch.

With the only one exception, statistically significant correlation was found between the breast-height diameters of progenies at the age of 11 and 22 years. Like in height growth, this reality indicates the opportunities of forecasting the further course of growth in thickness for progenies at as early as the age of 11 years. Reliability is lesser in this case than in height growth, however (the values of correlation coefficients are as follows: 0,55, 0,61, 0,81).

Stem Forming

At the age of 11 years the average share of trees with a satisfactory stem forming represents 89% (plot No. 32) up to 97% (plot No. 14) on the research plots. At the age of 22 years the registered share of such trees was conspicuously lower, namely 62 to 80%. This phenomenon may result from the fact that at the age of 22 years the forming of stem and its defects at ocular examination are more distinct. The morphological characteristic of stem at the age of 22 years is considerably revealed inter alia as a result of a very intensive height growth within the period from 11 to 22 years. A certain role might play subjective approach of different examiners, too.

Notwithstanding the mentioned facts, i.e. the considerable variation range between the progenies, the differences in the share of the trees with 1st and 2nd grade of stem form are statistically significant on the research plot No. 38 only. The realities above mentioned respond to the small shares of variance falling on the the progenies and low values of repeatability which vary from 0,08 to 0,67.

Comparing with the control (the progeny of clone No. 52-4-11 coming from open pollination), the stem forming (quality) of interspecific hybrids at the age of 22 years is conspicuously better and namely on all the three studied localities. The progeny of clone No. 52-4-11 coming from self-pollination manifests the better stem forming on plot No. 14 in comparison with the control, while on plot No. 32 it is vice versa. On both the plots the differences in stem forming are not statistically significant as far as the factor of progeny is concerned, however.

The highest share of trees with the satisfactory stem forming (the 1st and 2nd grade) are displayed particularly in case of progenies No. 84, 88, 81/2, on the research plot No. 38. In all the cases the progenies in question were hybrid.

ATTEMPT AT THE SYNTHETIC EVALUATION OF PROGENIES

The results of the analysis enable to evaluate synthetically the individual progenies from the viewpoint of all studied characters. On the research plot No. 14 the following trial variants can be classed as the most valuable ones: No. 79, 81/2, 86, on plot No. 32: No. 73, 76, 80, 80/1, on the locality No. 38: No. 81/1, 81/2, 84, 88. The value of progenies No. 81/1 and 81/2 should be especially emphasized. In both the cases the progenies in question are the combination of clones No. 52-4-11 x 2-4-12, where the paternal clone is represented by the Japanese larch from the Strážnice Forest Enterprise.

On the research plots evaluated within this report, the same progenies are represented partly. This fact enables to judge to what extent the effect of "localities" is exercised in the variance as a whole and what share out of the whole variance falls on the "residual" factor which can be in effect identified with the "progeny x locality interaction" factor. The effect of locality on the growth in height and thickness as well as on stem forming is statistically highly significant in the most of cases. Residual variance is mostly higher than the share of variance for localities. The statistical significance of "progeny" x locality interaction" factor cannot be judged on the basis of the used mode.

From the practical aspect it is important in what conditions the luxuriant growth of interspecific hybrids is more clear, whether on more rich soils, in good to optimum conditions, or rather on poorer sites. While on plot No. 14 the advance of interspecific hybrids compared with the progenies coming from open pollination is indicated only slightly, not being statistically significant, more conspicuous differences are visible both in heights and breast-height diameters on the two other research plots. As to larch this issue could be explained probably only on the basis of the synthetic evaluation of the whole system of plots which have been established with the larch progenies actually with interspecific hybrids so far.

DISCUSSION AND CONCLUSIONS

The share of the effect of paternal and maternal parent partners on the characters of progenies can be more reliably judged in those cases, when the progenies from reciprocal crosses are available. If it concerns the Mendelian inheritance, the basis is the first Mendel´s law of the identity od reciprocal crosses and homogeneity of the F_1 generation which we come from. When it is found out at the process of the evaluation of progenies from reciprocal crosses that the progenies are not identical, either participation or full implementation of extra-nuclear heredity (e.g. H r u b ý , 1961) should be presumed. On the one hand, in those processes not only the cytoplasm in the proper sense of the word could be applied but, on the other hand, also certain organelles in the cytoplasm presented, and plastids, particularly as to plants. It is known that in the Mendelian inheritance differences in reciprocal crosses may also occur in certain cases, but those are traits linked to the sex. The action of extra-nuclear genes is manifested mostly with matroclinity, i.e. more or less similarity, in some cases almost identity with the maternal parent individual.

The issue of extra-nuclear heredity and matroclinity has not been studied in forest tree species to some more sufficient extent yet. Certain tendencies regarding the possible differences in reciprocal crosses when crossing the European larch and Japanese larch can be deduced on the basis of the experience available until now (e.g. L a n g n e r , 1952, S c h o b e r , 1958). The fact that reciprocal progenies are not always identical is reflected between others in that the interspecific hybrids of the species mentioned are termed as *Larix eurolepis* Henry when Japanese larch is the maternal species, and *Larix leptoeuropaea* Dengler when it is European larch. The probability of extra-nuclear heredity when crossing forest tree species is indicated between others by L a n g n e r (1959) in connection with the hybridization work within the *Picea* genus.

On the basis of the results of evaluation interpreted in the foregoing chapters it can be generally concluded that the effect of various paternal partners, expressed in the variance falling on the progenies, was conspicuously lower for all the studied traits in the majority of cases in comparison with the residual variance representing the effect of maternal clone. In the literature data available, both domestic and foreign, no work has not been found out which had the similar orientation enabling to confront the results obtained on the plots No. 14, 32 and 38 with the findings from other conditions. As to the works published in Czech Republic the results received from the evaluation of progenies from reciprocal crosses within the *Larix decidua* Mill. species can be referred (Š i n d e l á ř , 1986). The results of the evaluation of heights, breast-height diameters and stem forming at the age of 9 and 16 years mostly document the more conspicuous effect of maternal clones on the progenies in comparison with that of paternal parent partners. This fact indicates a possible partial extra-nuclear heredity in European larch, particularly as far as the growth in height and thickness is concerned.

Apart from the plots No. 14 and 32, the progeny of clone No. 52-4-11 from self-pollination is represented also on some other plots of the 1969 and 1970 series, inter alia on plot No. 25 (Administration of Trial Forest Areas of the Forestry and Game Management Research Institute at Jíloviště). In quantitative traits, i.e. in height growth and breast-height diameter, the conspicuous "inbreeding" depression was investigated on this locality at the age of 9 years, except for standard heights (Š i n d e l á ř , 1986). In effect this complies with the theoretical assumptions (H r u b ý , 1961) as well as with the results of the research of other authors, particularly in larch (L a n g n e r , 1952, and others).

The advance of the larch interspecific hybrids registered on the plots No. 14, 32 and 38 is manifested in the number of other research plots of the 1969 and 1970 series, between others on the nine plots which have been evaluated at the age of 11 years (Š i n d e l á ř , 1983, 1988). The advance was extraordinary, compared with control (progenies from open pollination), it was higher by 5 to 22% in the height growth, by 7 to 31% in breast-height diameter and by 29 to 122% in volume yield. A number of other authors came to the analogous results (K i e l l a n d e r , 1958, 1974, D i m p f e l m e i e r , 1959, S c h ö n b a c h , 1967, L a n g n e r , 1971, G o t h e , S c h o b e r, B o r k , 1980, and others). In sporadic cases the interspecific hybrids lag behind in their growth. It results from a specific combination ability (S c h ö n b a c h , 1967, L a n g n e r , 1971, B r a u n , H e r i n g , 1987, Š i n d e l á ř , 1988). With regard to this fact the prerequisite of positive results in crossing is the choice of suitable parent partners on the basis of predetermined combination ability.

The finding of a number of authors (S c h ö n b a c h , 1967, S c a m o n i , 1977, and others) that interspecific hybrids within the *Larix* genus often do not satisfy with stem forming, was not proved on the plots No. 14, 32 and 38). The similar situation is also on the other studied plots of the same experimental series (Š i n d e l á ř , 1988).

Though the basic objective of the work is to judge the effects of various paternal clones on the progenies whose maternal clone is exclusively the clone No. 52-4-11, the results of the observations on the plots No. 14, 32 and 38 might be used for the judgment of the value of the progenies of individual combination crosses. Positive variants may be used for further breeding, between others as the original stock for the establishment of seed orchards to produce hybrid seed of the F_2 generation.

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S U P L E M E N T S

List of clones (trees) whose progenies are represented on the research plots

Table 1

Inventory number	Species	Forest Enterprise	Forest District	Altitude a. s. l. (m)	Place of origin	Age (years)	Height (m)	d. b. h. (cm)	Stem forming	Utilization		
										Open pollination	Controlled cross breeding ♀	Controlled cross breeding ♂
2-4-12	*L. leptolepis*	Strážnice	Vápenky	620	AL	34 (58)	18	22	1	—	—	/
3-4-12	*L. leptolepis*	Strážnice	Vápenky	620	AL	34 (58)	19	24	1	—	—	/
1-4-13	*L. decidua*	Bruntál	H. Benešov	600	AU	125 (58)	38	56	1	—	—	/
11-4-13	*L. decidua*	M. Albrechtice	Albrechtice	360	AU	80 (58)	25	42	1	—	—	/
41-4-11	*L. decidua*	Ruda nad Mor.	Ruda	480	AU	105 (58)	36	59	1	—	—	/
52-4-11	*L. decidua*	Ruda nad Mor.	Ruda	480	AU	105 (58)	32	40	1	/	/	/
61-4-11	*L. decidua*	Ruda nad Mor.	Ruda	480	AU	50 (58)	15	28	1	—	—	/
Ž 1	*L. leptolepis*	Žehušice	park	300	AL	90 (67)	22	58	3	—	—	/
K 1	*L. leptolepis*	Kostelec n. Č. l.	arboretum	350	AL	16 (67)	6	14	1	—	—	/
K 2	*L. leptolepis*	Kostelec n. Č. l.	arboretum	350	AL	16 (67)	7	15	1	—	—	/
K 3	*L. leptolepis*	Kostelec n. Č. l.	arboretum	350	AL	16 (67)	7	14	1	—	—	/
K 4	*L. leptolepis*	Kostelec n. Č. l.	arboretum	350	AL	16 (67)	8	17	1	—	—	/
R 2	*L. gmelini olg.*	Ratměřice	park	620	AL	40 (67)	16	26	2	—	—	/
B 1	*L. gmelini Princ. Rupr.*	Bukovina	arboretum	450	AL	45 (67)	14	28	3	—	—	/

List of cross breeding combinations on the research plots (VS — open pollination)

Table 2

Combination			Species (hybrid)	Research plot		
Ordinal number	♀	♂		14	32	38
72	52-4-11	11-4-13	*L d.* × *L d.*	/	/	
73	52-4-11	41-4-11	*L d.* × *L d.*	/	/	/
74	52-4-11	1-4-13	*L d.* × *L d.*	/	/	
75	52-4-11	52-4-11	*L d.* × *L d.*	/	/	
76	52-4-11	61-4-11	*L d.* × *L d.*	/	/	
77	52-4-11	K 1	*L d.* × *L l.*	/		/
78	52-4-11	K 2	*L d.* × *L l.*	/		
79	52-4-11	K 3	*L d.* × *L l.*	/		
80	52-4-11	K 4	*L d.* × *L l.*		/	
81/1	52-4-11	2-4-12/1	*L d.* × *L l.*	/	/	/
81/2	52-4-11	2-4-12/2	*L d.* × *L l.*	/		/
84	52-4-11	3-4-12	*L d.* × *L l.*	/		/
86	52-4-11	Ž 1/I.	*L d.* × *L l.*	/		/
88	52-4-11	Ž 1/II.	*L d.* × *L l.*			/
89	52-4-11	B 1	*L d.* × *L g.*	/		
91	52-4-11	VS/I.	*L d.*	/	/	/
92	52-4-11	VS/II.	*L d.*	/	/	
93	52-4-11	VS/III.	*L d.*	/		

List and brief characteristics of the research plot localities

Table 3

Research plot no.	Forest Enterprise	Forest Administration	Compartment, stand	Height a. s. l. (m)	Aspect	Slope (%)	Forest type	Previous stand	Planting year
14	SPLO Jíloviště	Jíloviště	17 L 2	340–350	S-E	5	rich hornbeam-beech stand	beech coppice with hornbeam	1969
32	Tábor	Bechyně	115 F	430	plain	–	acid oak-beech stand	forest nursery	1970
38	Pelhřimov	Dresden	520 B 7	640	S-W	5	rich pine-beech stand	unmixed spruce stand	1970

Methodic principles of the establishment of research plots (For all the plots generally: scheme — double lattice, 4 replications, spacing 2 × 2 m)

Table 4

Research plot no.	Forest Enterprise	Number of variants (combinations)	Number of parcels	Parcel size	Number of plants per parcel (pcs)	Number of plants per combination	Plants set out, total (pcs)	Size of area (m)	Total area without border rows (ha)
14	SPLO Jíloviště	16	64	6 × 6	9	36	576	48 × 48	0.2304
32	Tábor	9	36	6 × 6	9	36	324	32 × 32	0.1024
38	Pelhřimov	9	36	6 × 6	16	64	576	48 × 48	0.2304

Results of variance analysis for individual plots

Table 5

Research plot no.	Character	Age (years)	F	σ_p^2	σ_r^2	σ_0^2	h^2
14	height	11 22	1.33^{NS} 0.73^{NS}	0.007 –0.054	0.007 0.147	0.079 0.801	0.26
32		11 22	1.69^{NS} 3.13^{+}	0.062 0.747	0.153 0.080	0.358 1.403	0.41 0.68
38		11 22	1.35^{NS} 8.94^{++}	0.011 2.199	0.059 0.432	0.127 1.108	0.26 0.89
14	breast-height diameter	11 22	1.08^{NS} 0.53^{NS}	0.011 –0.237	0.006 –0.089	0.531 2.023	0.08
32		11 22	1.48^{NS} 6.66^{++}	0.185 5.849	0.104 1.096	1.544 4.135	0.32 0.85
38		11 22	1.75^{NS} 7.12^{++}	0.108 3.240	0.296 0.005	0.576 2.116	0.43 0.86
14	stem forming	11 22	1.20^{NS} 1.49^{NS}	0.003 0.008	0.001 0.012	0.054 0.067	0.18 0.32
32		11 22	1.00^{NS} 0.84^{NS}	0.000 –0.003	0.007 0.005	0.055 0.069	
38		11 22	2.81^{+} 3.23^{+}	0.012 0.031	0.004 0.017	0.026 0.056	0.63 0.69

F — test. crit. for progeny
σ_p^2 — average progeny effect
σ_r^2 — average replication effect
σ_0^2 — average residual effect
h^2 — repeatability (heritability)

Results of variance analysis for the system of plots at the age of 22 years

Table 6

Research plots no.	Character	F	σ^2_p	σ^2_l	σ^2_0
14, 32, 38	Height d. b. h. Stem forming	2.78^{NS} 1.35^{NS} 3.67^{NS}	0.7759 0.2329 0.1054	18.2657 8.0678 0.1671	1.3076 1.9948 0.1185
14, 32	Height d. b. h. Stem forming	0.68^{NS} 0.47^{NS} 0.31^{NS}	–0.2389 0.8848 0.0444	48.1785 21.2416 0.2051	1.4925 3.3149 0.1286
14, 38	Height d. b. h. Stem forming	10.41^{++} 6.96^{++} 1.38^{NS}	10.7027 3.9511 0.0177	0.7180 1.1778 0.0292	2.2753 1.3252 0.0943

F — test. crit. for progeny
σ^2_p — average progeny effect
σ^2_l — average locality effect
σ^2_0 — average residual effect

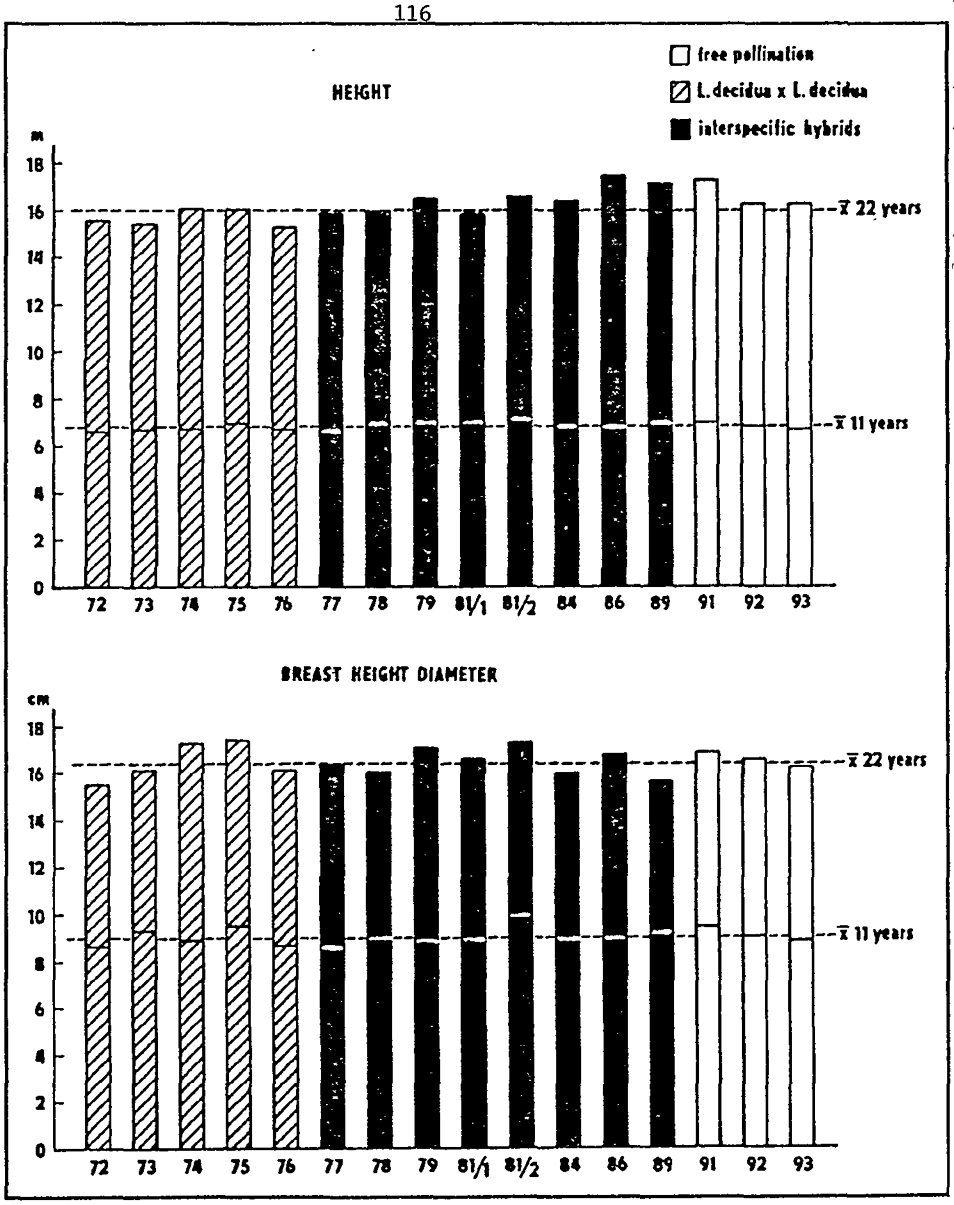

Fig. 1. Comparison of the averages (height, breast-height diameter) at the age of 11 and 22 years — research plot no. 14 (Administration of Trial Forest Areas of the Forestry and Game Management Research Institute at Jíloviště)

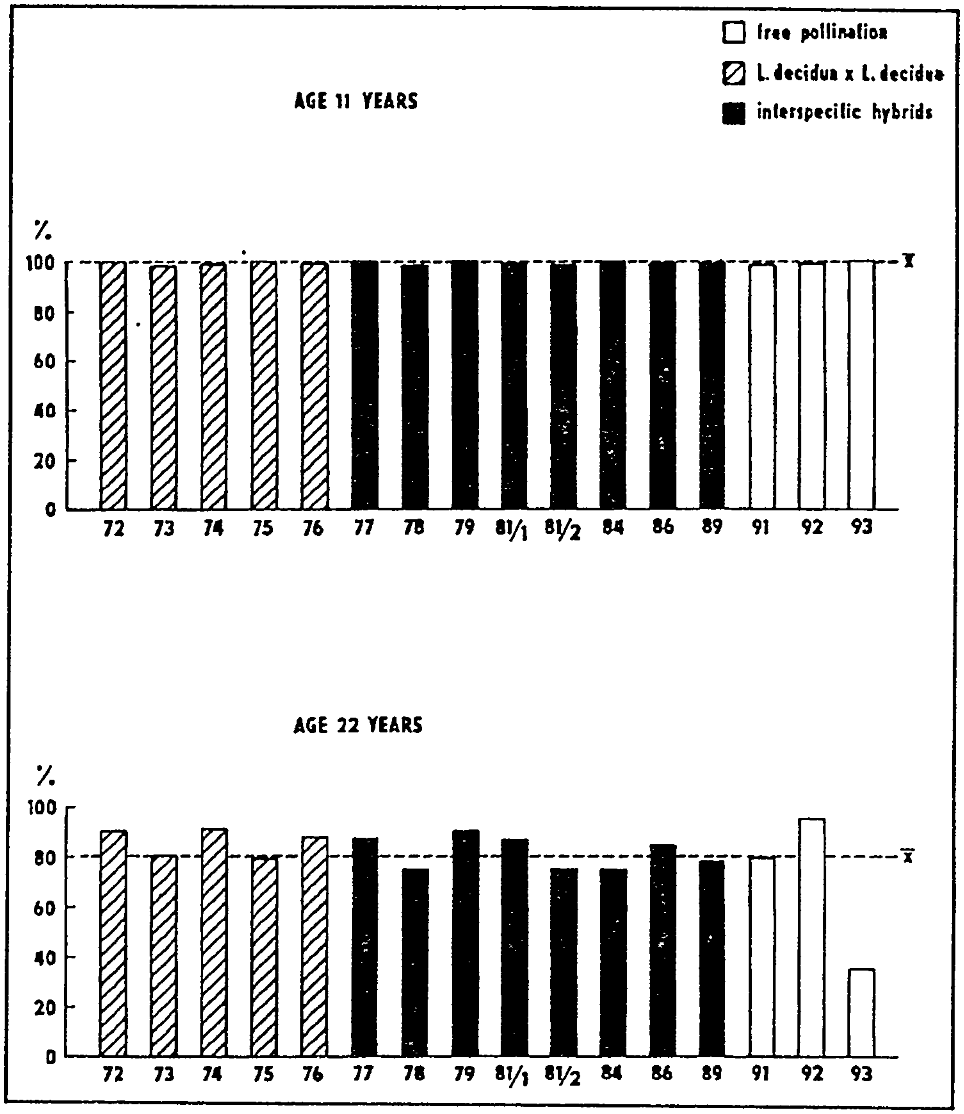

Fig. 2. Comparison of the average stem forming at the age of 11 and 22 years — research plot no. 14

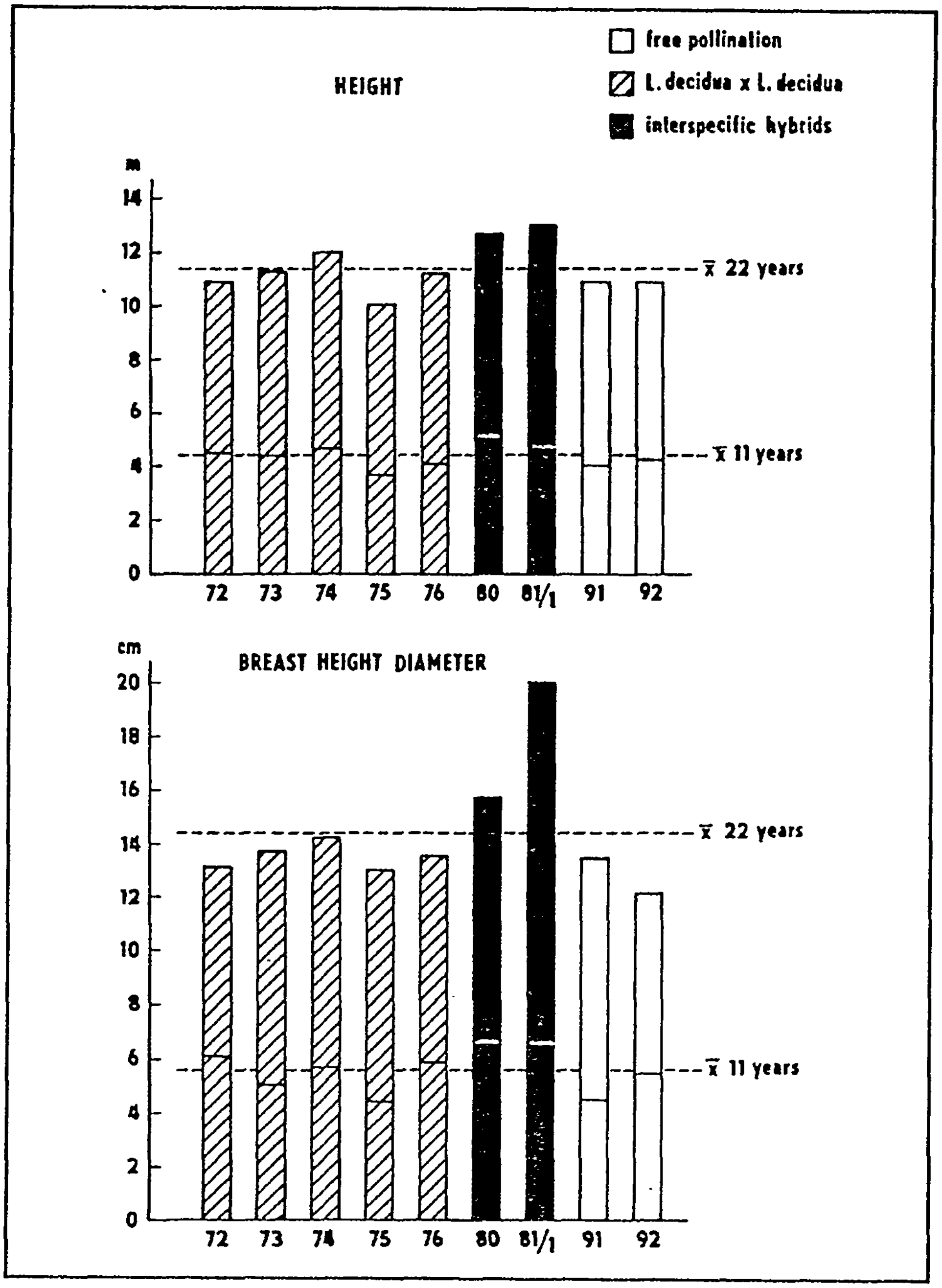

Fig. 3. Comparison of the averages (height, breast-height diameter) at the age of 11 and 22 years — research plot no. 32 (the Tábor Forest Enterprise)

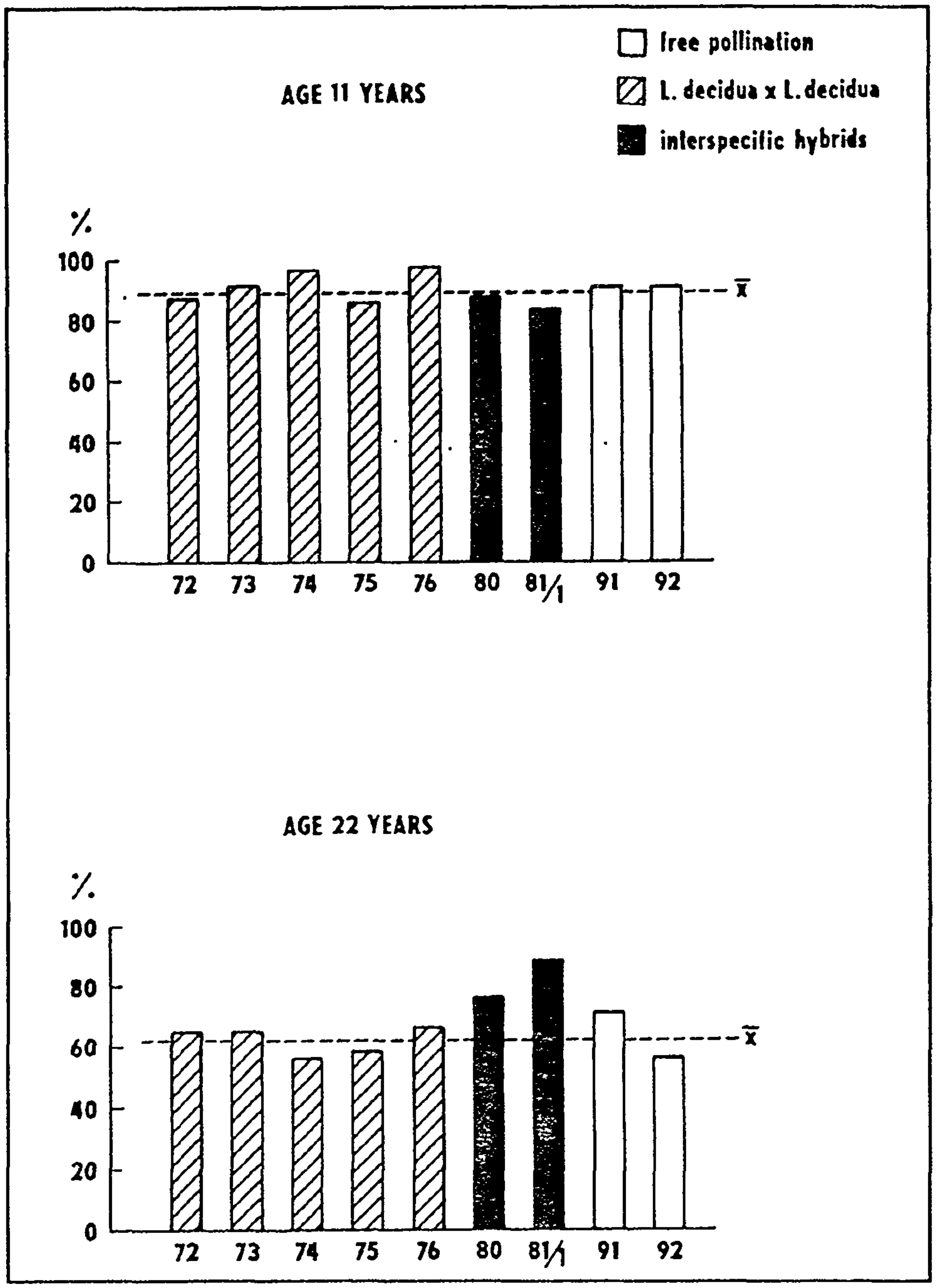

Fig. 4. Comparison of the average stem forming at the age of 11 and 22 years — research plot no. 32

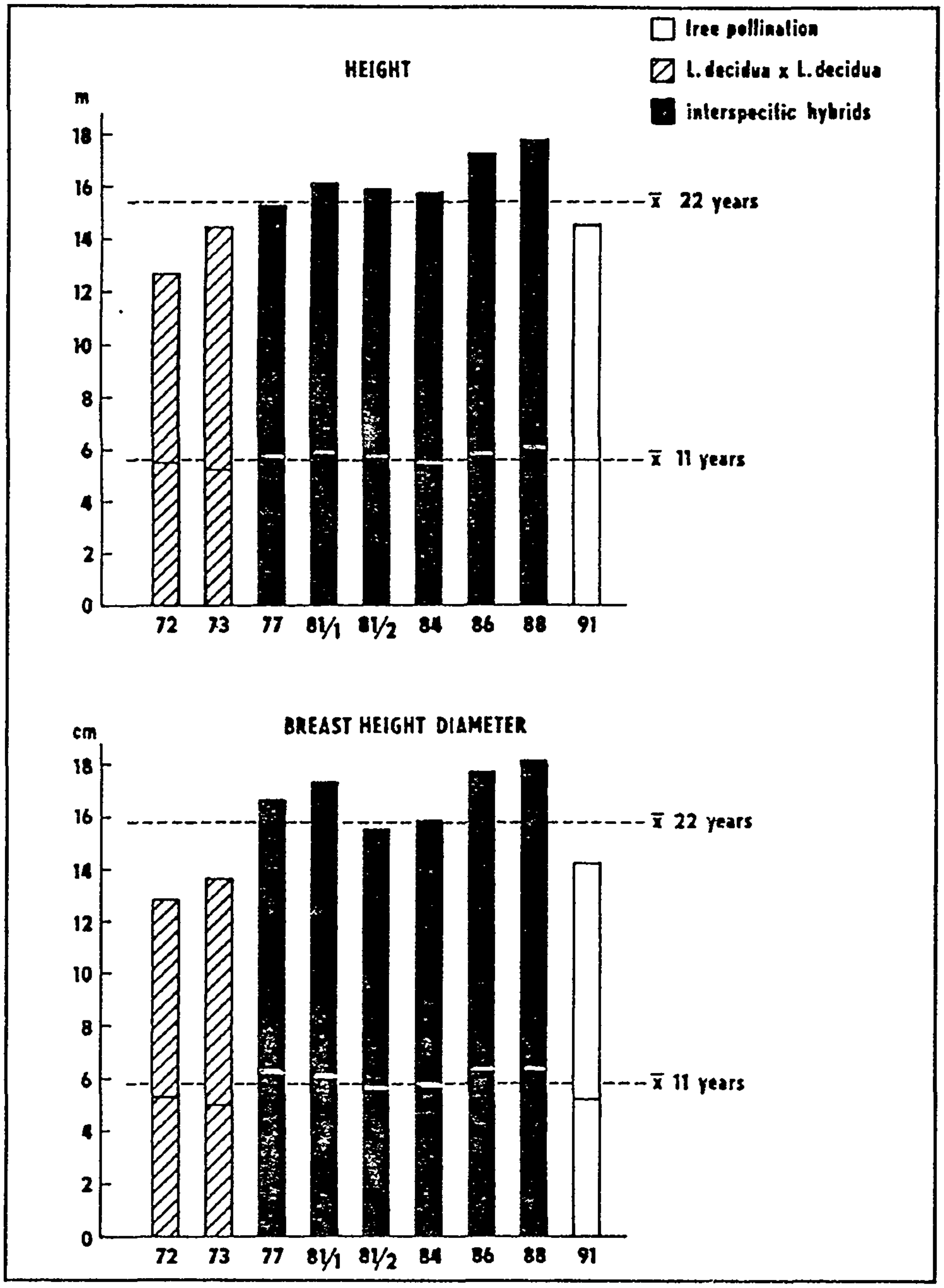

Fig. 5. Comparison of the averages (height, breast-height diameter) at the age of 11 and 22 years — research plot no. 38 (the Pelhřimov Forest Enterprise)

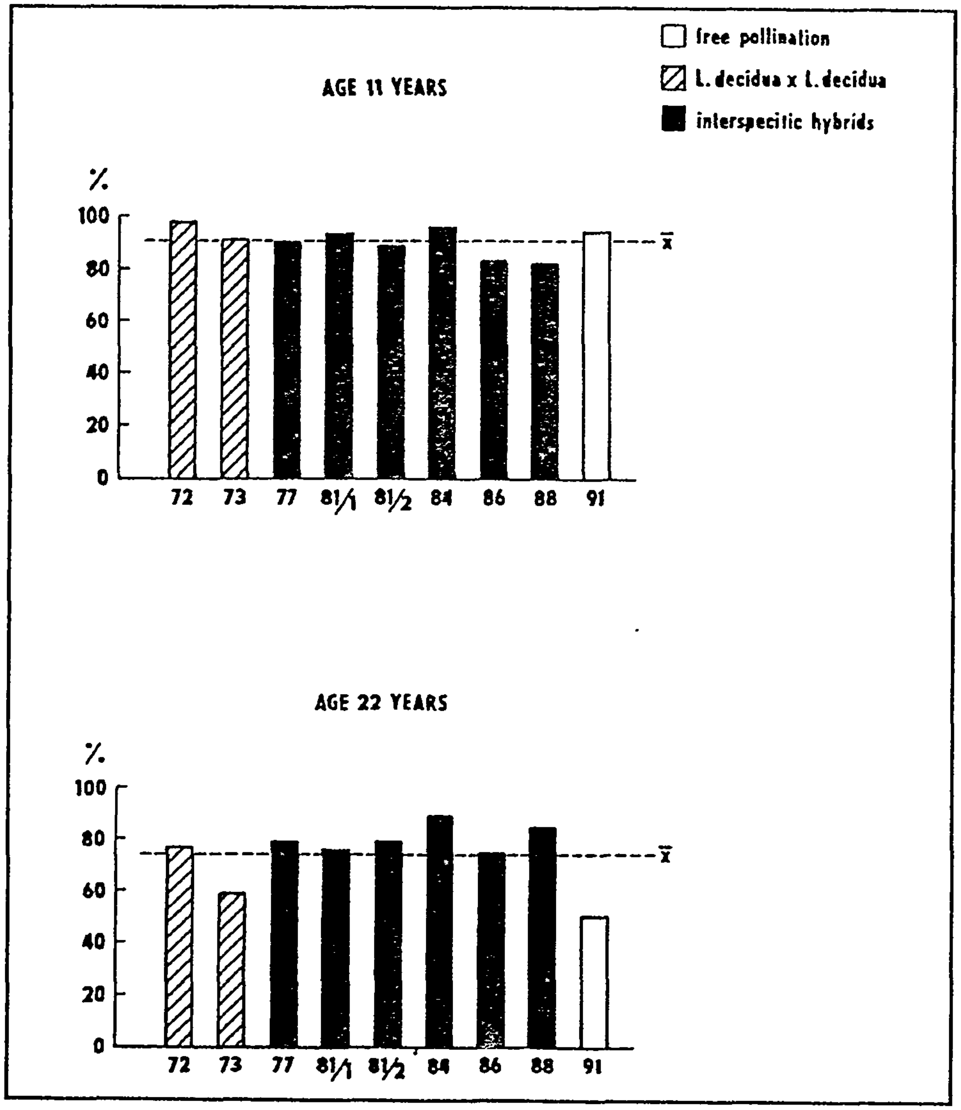

Fig. 6. Comparison of the average stem forming at the age of 11 and 22 years — research plot no. 38

RESULTS OF HYBRID LARCH BREEDING IN BADEN-WÜRTTEMBERG

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SUMMARY

Because of the increasing importance of well adapted Larch provenances for silvicultural purposes, Larch breeding activities were started in the 1950's in Baden-Württemberg. Plustrees of European larch (*Larix decidua* Mill.) and Japanese larch (*Larix kaempferi* (Lamb.) Carr.) were selected on different sites all over the country in order to establish seed orchards for providing high quality seeds to forestry enterprises.

Larix decidua as well as *Larix kaempferi* are not indigenous in Southwest Germany, but were introduced in many forests during the last 200 years. Forest tree breeders believed that the populations of the introduced species and provenances had already more or less geneticly adapted to the specific site conditions within one or two generations. In order to be independent from further reproductive material imports they built up several seed orchards with regional *Larix decidua* breeding groups and one *Larix kaempferi* clone collection.

Influenced by the fascinating results of hybrid larch breeding in other parts of Germany and Europe *Larix x eurolepis* Henry was chosen to be tested as a silvicultural alternative for special sites. By progeny tests hybrid larches should be compared to the progenies of Larch seed orchards in Baden-Württemberg. The objectives of the tests were:

- comparison of growth and stem form characteristics
- resistance to diseases and biotic or abiotic damages
- hybridization effects
- site influence

Between 1968 and 1976 controlled crosses were made in two Larix decidua seed orchards. Selected European larch clones were pollinated with defined poll mixtures from different Japanese larch clones as well as with poll mixtures from Alpine or Sudetic larches (*Larix decidua*). The poll mixtures varied every year.

62 cross combinations were tested, of which only 51 combinations were successfull. Unfortunately there were neither reciprocal crosses between the different species nor intra-specific crosses between different provenances, but there was some open pollination.

The hybrid and the pure species seeds were sown and grown (partly in containers) in the nursery of the Baden-Württemberg Forest Research Institute, Departement of Botany and Site Studies, at Stuttgart-Weilimdorf. At plant age 2 and 3 field trials were established in 6 forest districts of Baden-Württemberg on 9 different sites. Small blocks of hybrid larches were planted in mixture with blocks of *Larix decidua* progenies from various seed orchards and *Larix kaempferi* progenies from selected stands in Southwest Germany.

Although the layout of the experimental fields was unsatisfactory (e.g., there are no repetitions and the plant numbers per block differ) and a first carefull tending of the young stands had already taken place, the attempt was made to measure and to judge the progenies at age 20 (respectively age 15) on 5 experimental plots in order to get informations for further Larch breeding activities in Baden-Württemberg. The results are:

Growth characteristics

At age 20 (15) hybrids of Sudetic larch as mother and Japanese larch as father ($\bar{x}_h$: 16,5-18,8 m (12,5 m); $\bar{x}_{dbh}$: 24,6-27,9 cm (17,3 cm)) ranked highest. The second best cross combination was Alpine larch with Japanese larch ($\bar{x}_h$: 15,9-17,9 m; $\bar{x}_{dbh}$: 24,2-26,5 cm). Progenies of open pollinated Larix kaempferi ($\bar{x}_h$: 14,5-15,5 m (10,4-10,5 m); $\bar{x}_{dbh}$: 20,5-21,4 cm (15,3-16,3 cm)) exceeded open pollinated progenies of Larix decidua ($\bar{x}_h$: 12,2-14,0 m (10,7); $\bar{x}_{dbh}$: 18,7-21,3 cm (14,7 cm)) in growth, but both laged behind the hybrids. Within European larch progenies sources from the Sudetes grow better than Alpine provenances.

Form

Considering possible tending effects a summarizing assessment of the stem forms was difficult. Variing from site to site most of the hybrids and most of the intra-specific progenies had less than 20% of absolutely straight boles. Only a couple of cross combinations as well as some seed orchard progenies and selected stand progenies on specific sites showed better results, but without any tendency. The rest can be described by a more or less serpentine shape of the stems partly in combination with sabre like, crooked growth.

Resistance

Most of the progenies were in good health condition. There were no signs of missing vigour or diseases. However there were some frost damages (frost cracks) on the boles. They were especially found on mountainous sites (26-82 %), but without any preference neither to the hybrids nor to the pure species.

Hybridisation effects and site influence

The superiority of the hybrid larches over their parents species was obvious, although a statistical verification was not possible because of the unsatisfactory experiment design.

Conclusion

Drawing a conclusion it has to be admitted that the first experiments with controlled crosses of Larch species in Baden-Württemberg were insufficient. Although the growth performance of many hybrids is good, it is not yet possible to recommend one or several cross combinations for silvicultural purposes, because a clear judgement of the adaptability of the hybrids to Southwest German forest sites is missing as well as informations about wood quality.

Nevertheless the importance of fast and well growing hybrid larches as a renewable resource will probably rise in future. Therefore the results of the old cross experiments should be considered as pre-studies for further hybrid larch breeding activities in Baden-Württemberg.

GROWTH RESPONSES OF *LARIX* HYBRIDS BETWEEN *L. KAEMPFERI* AND *L. GMELINII* VAR. *JAPONICA* WITH ALTITUDINAL GRADIENT

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SUMMARY

To test the adaptability of Japanese larch, Dahurian larch and their hybrid to the environment in Hokkaido, these three materials were planted and surveyed of their survival and growth for 30 years at four elevation in central Hokkaido, northern Japan.

Japanese larch showed low adaptation with high mortality affected by voles at every elevation. Dahurian larch has high vole resistance but showed high mortality caused by the infection of *Armillaria* root rot. Hybrid could persist through low to high elevation. Only hybrid showed enough growth at the highest elevation.

Stress tolerance of hybrid was confirmed under high altitudinal condition.

Key word: Altitudinal test plantation, Dahurian larch, Hybrid, Japanese larch

INTRODUCTION

Hybrid between species often show superior trait than two parent species. This phenomenon has been reported on various plant species and is called hybrid vigor (Wright, 1976). Hybrid between Japanese larch (Larix kaempferi) and Dahurian larch (L. gmelinii var. japonica, Kuril or Sakhalin larch in a narrow sense) also show excellent characters, fast growth (Kurahashi, 1988) and resistance against red-backed vole (Takahashi and Nishiguchi, 1966). So the hybrid is one of the main tree species planted for cultivation in Hokkaido, Northern Japan.

Japanese larch distribute in central Honshu, Japan. Dahurian larch distribute on Kuril Islands and in Sakhalin (Farjon, 1990). The warm index is between 15℃ and 75℃ in the natural distribution of Japanese larch (Hayashi, 1960) and between 12℃ and 41℃ in that of Dahurian larch (Takahashi et al, 1968). As to the climate on natural distribution, the former belong to inland and the latter to oceanic. Neither Japanese larch nor Dahurian larch distribute in Hokkaido. These two species has been planted for about 100 years in Hokkaido. The first hybrid between these species were reported in 1939 (Ishihara and Matsukawa, 1939).

The ecological characters has not fully surveyed on these species and their hybrid in Hokkaido in spite of the popularity. Survival rate and tree growth was studied on these two species and hybrid which were planted at four different altitude to clarify the fittest environment (altitude) for each materials.

EXPERIMENTAL METHODS

Study site

The study site was located at The Tokyo University Forest in Hokkaido (142° 18′ ~40′ E, 43° 10′ ~20′ N), central Hokkaido. The mean annual temperature, annual precipitation, and warm index are 6.8℃, 1300mm, and 64℃, respectively. Most part of the University Forest belong to the cool-temperate zone where mixed forest with conifer and deciduous broad-leaved trees cover.

Four plots numbered I, II, III and IV were set over the Mae-yama slope at different altitude, 530m, 730m, 930m and 1100m above sea level, respectively (Fig.1). Each condition of plots is shown in Table 1. Plot I and II belong to the upper part of cool-temperate zone. On the other hand, plot Ⅲ and Ⅳ belong to sub-alpine zone. There occur a enormous difference of Temperature and flora between plot Ⅱ and Ⅲ.

Table 1. Study plot

	Alt.(m)	MAT	WI	CI	Forest type
I	530	5.9	59.2	-48.5	Abies sachalinensis, hard wood
Ⅱ	730	4.4	51.7	-54.0	A. sachalinensis, Picea jezoensis, Tilia japonica
Ⅲ	930	0.1	30.5	-88.8	P. jezoensis, A. sachalinensis, P. glehnii
Ⅳ	1100	-0.2	28.2	-91.0	P. jezoensis, P. glehnii, Betula ermanii

MAT; Mean annual temperature, WI; Warm index, CI; Cold index
Temperature was measured from 1973 to 1975 (Tokyo Univ. For. in Hokkaido, 1978).

Materials

Plant materials are Japanese larch, Dahurian larch and their hybrid (Dahurian larch × Japanese larch)(Table 2). Seed of Japanese larch were derived from Nikko, Northern Kanto. The provenance of the Dahurian larch is not certain, but is supposed to be Kuril Island. Seed of the hybrid were obtained from the Dahurian larch and the hybrid were selected on the basis of seedling character at the nursery in the University Forest.

Table 2. Plant materials tested in the altitudinal plantation

Materials	Provenance	Seed source	Number	Year	Age
Dahurian larch	Kuril (unsure)	Wakkanai Forest Office	224×2	1959-1960	2-year
Japanese larch	Nikko, Japan	Utsunomiya For. Office	224×2	1959-1960	2-year
Hybrid (Japanese larch × Dahurian larch)		Tokyo Univ. For. in Hokkaido	224×2	1960	2-year

Number: Number of seedlings, Year: Year of plantation, Age: Seedling age when planted

Methods

In order to check the availability of each species under high altitudinal condition, 224 seedlings × 2 for three materials were planted at four plots between 1959 and 1960. The number of survived trees was counted and those of DBH were measured in 1965, June 1981, and November 1989. The tallest six individuals were measured of their height in 1989.

RESULTS

As to the capability along to elevation change, the survival ratio for three materials in 1989, 30 years after plantation, were shown (Fig. 2). The survival ratio for Japanese larch showed remarkable decrease as the elevation of plots became higher. The survival ratio for Dahurian larch was the lowest among three materials at low elevation (I), but was kept about 20 % up to plot Ⅲ (930m). The hybrid showed higher survival ratio than two parent species at all plots. The highest survival rate of the hybrid was appeared at plot Ⅲ. It was also proved that the hybrid could grow at high elevation (plot Ⅳ) where two parent species especially Japanese larch were very hard to survive.

Survivorship curves were shown for each materials (Fig. 3). The highest mortality was appeared to both Japanese and Dahurian larch for the first five years at all plots. This phenomena did not occurred on the hybrid at all plots. The survival of Japanese and Dahurian larch decreased to nearly 0.0 % at plot Ⅳ in 1981 (22 years after plantation). Survival ratio for all materials had not changed so much between 1981 and 1989 at every plot.

As to mortal factor, the attack by red-backed vole shore the most part of the reason for decrease of Japanese larch at every plot. Dahurian larch was attacked by Armillaria root rot. Though the hybrid was also attacked by vole as well as Armillaria root rot, the damage was comparatively slight.

The height growth reduced for all species as altitude elevate (Fig. 4). Dahurian larch showed lower growth in height than others at every plot. Both Japanese larch and the hybrid showed similarity in height growth at plot I~Ⅲ. The hybrid grew well even at high elevation (Ⅳ).

To estimate the productivity, D^2H was calculated about tallest six individuals for each materials (Table 3).

CONCLUSIONS

Japanese larch would only suit to grow at low elevation, Dahurian larch would up to 930m, and the hybrid would up to 1100m judging from the survival rate. Low resistant to voles and deep snow was considered as the most effective factor to decrease the number of Japanese larch at high elevation. Dahurian larch showed inferior growth trait to Japanese larch at three plot. The hybrid was not so damaged by voles nor deep snow fall in central Hokkaido.

Dahurian larch stop its growth and form winter bud one month earlier than Japanese larch to get frost hardiness earlier than Japanese larch do (Hamaya et al ,1967). So the growth rate of Dahurian larch is lower than that of Japanese larch. The hybrid show intermediate phenology of shoot which would result in tolerance in frost hardiness as well as in higher growth rate than Dahurian larch.

Judging from the tree size (D^2H), Japanese larch would suit for silviculture under 500m, Dahurian larch would under 730m, and the hybrid up to near the tree line in central Hokkaido.

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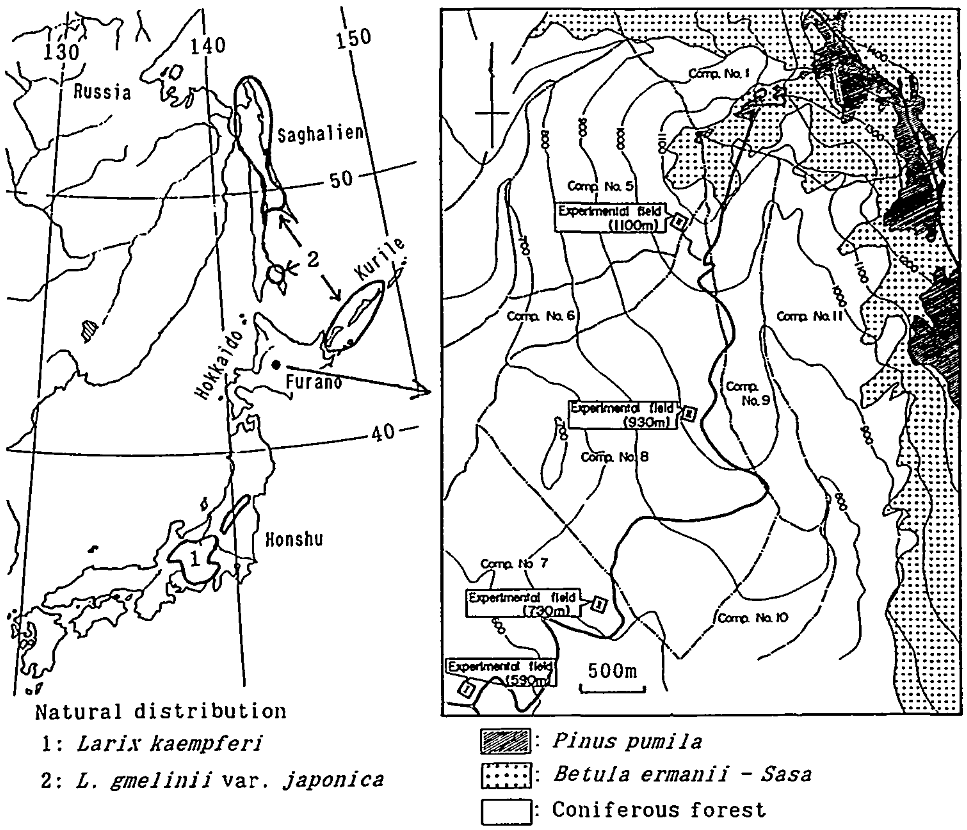

Fig. 1. Natural distribution of Japanese larch (Larix kaempferi) and Dahurian larch (L. gmelinii var. japonica) and the location of study site in the Tokyo University Forest in Hokkaido.

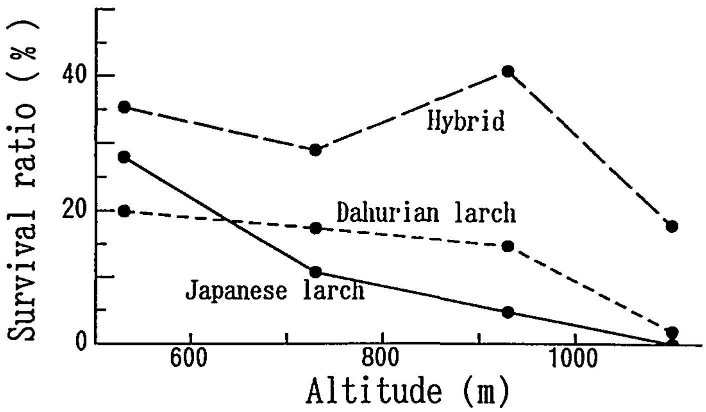

Fig. 2. Survival ratio for Japanese larch, Dahurian larch and their hybrid at four elevation in 1989, 30 years passed after plantation.

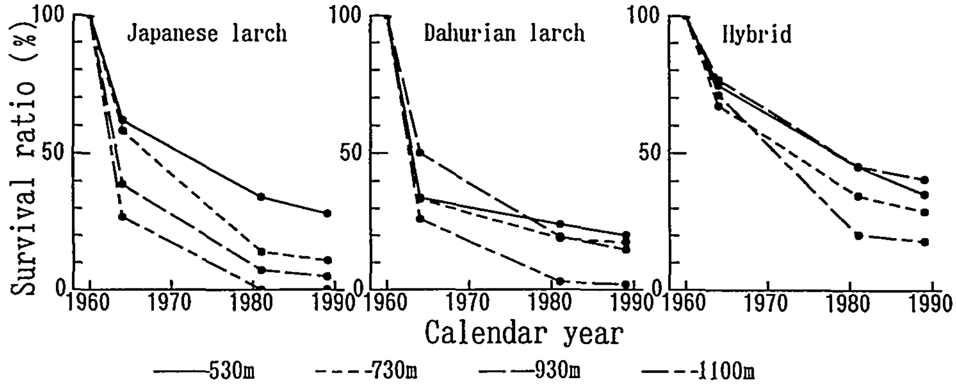

Fig. 3. Survivorship curves for Japanese larch, Dahurian larch and their hybrid at four elevation from 1960 to 1989.
Number of materials was 448 for each species at each elevation.

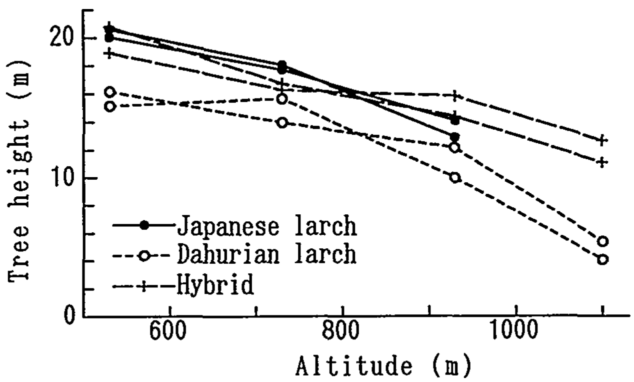

Fig. 4. Mean tree height for Japanese larch, Dahurian larch and their hybrid at four elevation.
Mean tree height was calculated with the six tallest trees among each materials.

Table 3. Tree size of Japanese larch, Dahurian larch and their hybrid at four elevation.

Species		Altitude (m) 530	730	930	1100
		D^2H (m^3)			
Dahurian larch	AVG	0.64	1.01	0.52	0.06
	STD	0.17	0.36	0.39	0.04
Hybrid	AVG	0.93	0.94	0.70	0.56
	STD	0.28	0.29	0.29	0.22
Japanese larch	AVG	1.49	1.61	0.82	
	STD	0.37	0.37	0.23	

D^2H was calculated with the six tallest trees among each materials.
AVG: average, STD: standard error

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Strategy for Larch Breeding in Iceland

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Abstract

An accelerated breeding program for Siberian larch was initiated in Iceland in 1992. Siberian larch is an important exotic species, but not fully adapted to Icelandic conditions. Selections are made based on adaptive traits such as growth rhythm and resistance to damage as well as form and growth rate. Seed will be produced in containerised, greenhouse orchards, necessitating selection for fecundity to best use expensive greenhouse space. Research will concentrate on developing flower induction treatments for Siberian larch and ways to maximise seed production and viability.

Key words: *Larix*, tree improvement, containerised seed orchards.

Introduction

Afforestation in Iceland is carried out for land reclamation, commercial forestry and amenity purposes. The most commonly planted species are the native birch (*Betula pubescens* Ehrh.), Siberian larch (*Larix sibirica* Ledeb.), lodgepole pine (*Pinus contorta* Dougl.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Larch is planted for all the above mentioned purposes and is currently the most important species planted for wood production.

Larch was first introduced to Iceland shortly after 1900, but only a few trees planted before 1938 survive. The first true Siberian larch plantation was planted in 1938. At age 55, in 1993, the mean annual increment was 7.5 m^3/ha/yr. and the mean dominant height was 17m (Benedikz unpublished data).

Continuous planting of larch did not begin until after 1950, when contacts were established in the Soviet Union. Since then, Siberian larch from approximately 50 provenances and seed orchards has been planted in Iceland (Thorsteinsson 1994). In recent years, most larch seed has been bought from Finnish seed orchards. Other larch species have been planted in Iceland, but on a much smaller scale.

Larch planted in Iceland originated mainly in two regions; the Archangelsk district in northwestern Russia and the vicinity of the Altai mountains in southern Siberia. Larch from western Russia is sometimes classified as a separate species, *Larix sukaczewii* (Dylis). Whether it is a true species or not is questionable. However, in Iceland we call this larch Russian larch and provenances originating from east of the Urals Siberian larch. This distinction is useful in Iceland because there are measurable differences in growth and adaptive traits between them.

Stem form of Russian larch is considerably better than that of Siberian larch (Snorrason 1987). Russian larch looses frost hardiness in the spring faster than Siberian larch (Skúlason 1994). Although overall growth rate is similar, Russian larch tolerates cool summers better and Siberian larch utilises warm summers better for diameter growth (Lindhagen 1990). Russian larch tolerates both larch- and conifer canker (*Lachnellula willkommii* (Hart) Dennis and *Potebniamyces coniferarum* (Hahn) Smerlis) better in Iceland than

Siberian larch, probably due to better tolerance of cool summer conditions (Eysteinsson et al. 1994). The general outcome is that Russian larch is preferred because of better form, although some Siberian provenances are better than some Russian provenances and good individuals are found within most provenances.

Larch improvement in Iceland has proceeded in several steps. By 1950, it was clear that *Larix sibirica* grows well in Iceland (Blöndal 1964) and by the 1980's it was obvious that Archangelsk district provenances were usually superior to provenances from farther east.(Snorrason 1987). Today, there is no indication that Russian larch of Finnish or Swedish seed orchard origin is better in Iceland than larch of non-select parentage from natural stands. After all, trees in Finnish and Swedish seed orchards were selected for growth under Finnish and Swedish conditions and improvement efforts there do not necessarily mean that the trees will be improved with respect to Icelandic conditions, where the summers are cooler and the winters milder at similar latitudes.

It has also become clear that, although Russian larch grows well in interior valleys in northern and eastern Iceland, it suffers damage from conifer canker in the more maritime southern and western parts of the country. There, European larch (*Larix decidua* Mill.) even fares better in some places because it maintains frost hardiness during warm periods in winter, although it is regularly damaged by fall frosts. Centuries of sheep grazing have led to vegetation decline and soil erosion in all parts of Iceland. Larches tolerate impoverished soils better than most other tree species and it is therefore desirable to use them in all parts of Iceland.

A breeding program for larch was initiated in Iceland in 1992 (Eysteinsson 1993). The purpose is to insure a constant supply of seed of well adapted, fast growing, straight larch. To begin with, efforts will concentrate on improving Russian larch for interior north and east Iceland. Various hybrids and species for use in other parts of the country will also be made and tested.

Most breeding programs for larch are based on single stage selection and traditional seed orchards. This system has several drawbacks, including; a long period from selection to seed production, relatively few clones produce most of the seed, low and sporadic seed production, poor seed viability and difficulty in introducing new clones. In some cases, the best seedling families are multiplied via rooted cuttings, but this is expensive and only done because seed production is not adequate (Jaques and Nanson 1989). In the breeding program described here, attempts are made to overcome these drawbacks by using accelerated techniques, including containerised indoor orchards, early flower induction and early progeny testing.

Selection

A three stage selection process will be used. The first stage is based on selection for both adaptation and growth traits. Clones are selected from plantations in Iceland, ranging in age from 10 to 57 years. Selected trees must be without evidence of frost or canker damage or, if the terminal leader has been damaged, show immediate straight growth above the damaged section. They must be straight and as tall or taller than the surrounding trees. Lateral branches should be fine and grow at close to a 90° angle to the trunk.

The second stage will be based on fecundity. Clones with very low fecundity will not be maintained in the breeding program because seed production will take place in greenhouse orchards, where space is limited. The problem of low fecundity of some clones is well known in tree breeding and has not been solved though many have tried. We do not expect to be able to resolve it, although we may also try.

The third stage of selection will be based on progeny tests. Trees producing the poorest progeny will be gradually removed from seed production as information becomes available.

Selection of clones will be an ongoing process. Instead of selecting a large initial population and making advance selections only from their progeny, a small initial population will be augmented by new trees as they are discovered and advance generation progeny as they become available. Thus, future seed orchards could consist of a mixture of original clones, their progeny and clones selected later. There are two main reasons for continuing selection of new clones. 1) Large plantings of seedlings originating from two Finnish seed orchards, Imatra and Lassinmaa, and from natural stands in Russia have recently been made in Iceland. These are still too young to select plus trees from, but could yield selections within the next 10-20 years. 2) New genetic material will continue to be imported from natural stands in Russia whenever the opportunity presents itself and the possibility of finding plus-trees within these new plantations will continue.

A total of 48 clones have so far been selected and grafted; 43 Russian larch, 4 Siberian larch and 1 of unknown origin. In addition to these, grafts and seedlings of European larch (*Larix decidua* Mill.), Japanese larch (*Larix leptolepis* (Sieb.& Zucc.) Endl.), their hybrid (*Larix x eurolepis* Henry), Tamarack (*Larix laricina* (Du Roi) K. Koch), subalpine larch (*Larix lyallii* Parl.) and subalpine x western larch hybrid (*Larix x lyallocci* Carlson) are included for research purposes.

Indoor orchards

Seed production will take place in containerised, greenhouse orchards at Vaglir tree nursery in northern Iceland. Branches from select trees are grafted onto Russian larch seedling rootstock, several ramets per clone, and grown in pots in a 2/3 peat-1/3 pumice medium. The nutrient source is time-release fertiliser (6-month Osmocote with trace elements). The grafts are kept in the greenhouse the entire year. The greenhouse is heated only to keep the temperature above freezing from the time buds start to swell (usually in late March) and to maintain a temperature of at least 20°C during cool, cloudy days in June (when cone buds are differentiating). Otherwise, the greenhouse is not heated.

Indoor, containerised orchards not only provide ideal conditions for rapid growth and flowering, they also make it very easy to upgrade the clonal makeup of breeding populations as new selections are made (Ross 1985). Indoor orchards have been used successfully for tree breeding research for many years, but, with the exception of Finnish birch orchards, not for commercial seed production (Lepisto 1973, Eysteinsson et al. 1993). This will therefore be among the first attempts to produce conifer seed in commercial quantities in greenhouse orchards.

We expect some seed production to start in 1996, from ramets grafted in 1993, and considerable seed production by 1998. The clonal mixture used for seed production will continuously change as clones are removed due to low fecundity or based on progeny test results, and new clones added as the state of knowledge increases. One clone, selected in 1992, has already been eliminated because the original tree was damaged by conifer canker in 1993, and another because of failure to graft. The minimum number of clones used for seed production will be 10-15 at any one time.

Flowering

Results of flower induction treatments for larch have been mixed. Stress treatments, such as drought, are often not effective, but treatments such as girdling and application of the plant growth regulator gibberellin $A_{4/7}$ sometimes work well to increase flowering. (Bonnet- Masimbert 1982, 1987, Eysteinsson and Greenwood 1990, Ross

1991, Philipson 1995). However, greenhouse conditions, especially heat, probably do the most to promote flowering (Ross 1985, Eysteinsson et al. 1993).

Container-grown grafts of European larch averaged over 300 seed cones per graft in the fifth year from grafting (M.S. Greenwood unpublished data). Based on 50% viability and about 100 seeds per cone (Eysteinsson et al. 1993), each graft can be expected to produce an average of 15,000 viable seeds per year. Although this has not been tried with *Larix sibirica*, there is no reason to expect that it will behave very differently with respect to flowering.

The current demand for larch seed in Iceland is roughly 2,000,000 germinating seeds annually. Based on the results with European larch, these could be produced on as few as 133, 3.5 m tall, potted larch grafts growing in a greenhouse. Each tree requires about 5 m^2 of greenhouse floor-space, which means that the seed required could be produced in a 700 m^2 greenhouse. Even if the grafts only flowered half as well, doubling the space required, it would still only require 2 medium size greenhouses or one big one.

Milestones in the Icelandic accelerated larch breeding program.

1992	*first 19 clones selected*
1993	*first clones grafted, 30 more selected*
1995	*first flowering, first flower stimulation treatments*
1998	*considerable seed production, first progeny test planted*
1999	*culling of poor-flowering clones begins*
2000	*indoor orchards supply most of the larch seed needed*
2005	*parental selection based on progeny test results*
2012	*second-generation selections from progeny tests*

Research

Breeding research has been carried out in indoor, containerised orchards of European larch, Japanese larch, tamarack and western larch (*Larix occidentalis* Nutt.) (Eysteinsson et al. 1993, Danielson et al. 1992). All respond well to greenhouse conditions, but they respond differently to other cone induction treatments. Tamarack responds better to $GA_{4/7}$ than European or Japanese larch, which respond better to girdling and heat only (Eysteinsson et al. 1993, Philipson 1995). A series of experiments will be carried out to test how Siberian larch responds to various treatments intended to stimulate flowering.

Poor seed viability is a chronic problem in larch seed production in outdoor orchards (Kosinski 1987). Breeding in a greenhouse should prevent some of the problems that cause poor seed viability. Bad weather during pollen flight and late frosts will not be problems for example. Research will be carried out on ways to insure the best seed viability possible, including supplemental pollination and manipulation of the environment during seed ripening.

One goal of the research phase of the program is to identify recalcitrant clones. It is generally the case with conifers, and larches are no exception, that poor-flowering clones do not respond well to flower induction treatments. Since seed production will take place in greenhouses, where space is very valuable, poor-flowering clones will gradually be rogued out of the program.

Controlled crosses will be made to create a series of full-sib and half-sib families for progeny testing. Progeny testing will include early tests of frost hardiness and growth rhythm, as well as traditional field trials. Progeny test results will ultimately determine the makeup of the seed orchard and eventually be used for selection of clones for advance generation breeding. Since new clones will continuously be added to the breeding population, it will be necessary to plant small progeny tests regularly.

The question of after effects of the greenhouse environment on seedling adaptive traits (Johnsen 1989) will be addressed if there is any indication that seedlings from the indoor orchard are less well adapted than their parents.

Other species and hybrids

Both European and Japanese larch clones, as well as their hybrid, are included among the selections. Hybrids of these and Siberian larch will be made and tested, especially for use in southern and western Iceland. Tamarack is also included for hybridisation research with Siberian larch. Finally, a small number of subalpine larch clones selected in Iceland will form a separate breeding population. Subalpine larch is little tried in Iceland (or elsewhere for that matter), but the few existing trees grow well and this may be a species that can be grown at higher elevations than others in Iceland. Subalpine larch seed is practically impossible to obtain, so we will produce some indoors.

Conclusion

The Accelerated Siberian larch breeding program in Iceland is off to a good start. Grafting has gone well and many of the grafts grew to over 2 m in height in the second year after grafting. We expect considerable seed production by 1998, 5 years after the first grafts were made.

Acknowledgements

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GENETIC VARIABILITY OF WOOLLY APHID (*Adelges laricis* Vall.) RESISTANCE IN EUROPEAN LARCH (*Larix decidua* Mill.)

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ABSTRACT

One hundred and eleven clones of European larch were exposed to the woolly aphid and then outplanted in three locations using a randomised complete block design . At ages 11 and 19 resistance was measured on 102 clones at 2 locations. Highly significant genetic differences were observed among the clones at both locations and at both ages . Highly significant clone x location , clone x age and clone x location x age interactions were also observed . Differences between the most resistant and most susceptible clones was 483 %. Sufficient genetic variation for a breeding program was present . Broad-sense heritability estimates for *Adelges* resistance varied by location . Significant age to age , location to location and age to location phenotypic correlations for resistance were found . Larch resistance seems to be under polygenic control . A substantial genetic gain could be achieved by selecting the best clones and using vegetative propagation , including somaclonal embryogenesis , for multiplication .

Key words : *Larix decidua* , *Adelges laricis* , variance compnents , heritability, genetic gain ;

INTRODUCTION

European larch (*Larix decidua* Mill.) , a native species in the Alps and the Carpathians , is important for the high volumes of wood produced , its wide ecological amplitude , and its high resistance to most injurious factors. Nevertheless , attacks by the larch canker (*Dasyscypha willkommii* (Hart) Rehm.) , and insects such as the larch-mining moth (*Colleophora laricella* Hb.) and woolly aphid *Adelges laricis* Vall.) , results in some mortality or decreased vigour (Georgescu, et.al., 1958; Sindelar and Hochmut 1967, 1972).

The woolly aphid may cause significant damage in seed orchards of larch. The feeding activity at the base of flower buds may result in less than fully developed male and female flowers which in turn may substantially reduce cone production (Sindelar and Hochmut, 1967).

The existence of larch resistance to woolly aphid has been observed. Larson (1953) and Robak (1961) found that woolly aphids occurred in large numbers on European larch but only sporadically on Japanese larch (*Larix leptolepis* Gord.). These finding were verified by Eidmann (1966) who also observed different levels of attack within a trial of European larch provenances. Looking at trees exposed to natural attacks, Sindelar and Hochmut (1967) found highly significant differences in resistance among different seed sources of European larch. They also confirmed that resistance in Japanese larch was higher than in European larch.

Investigations carried out in Romania (Blada, 1977, 1982, 1988) on larch demonstrated the following:

(1) -There was significant individual phenotypic variation in attack of woolly aphid in European larch populations;

(2) -This phenotypic resistance to woolly aphid was largely attributed to genetic causes and was heritable;

(3) -The Japanese larch resistance was much higher than that of European larch.

This paper summarises the results , at ages 11 and 19 , of a study of genetic variability of woolly aphid resistance in European larch clonal trials planted in different environments.

MATERIALS AND METHODS

One hundred and eleven apparently resistant trees were selected from 20 natural and planted European larch stands that had been extensively attacked by woolly aphid. Selection was based on the variability of phenotypic resistance observed within these populations.

Grafts of the selected trees were made on rootstocks transplanted in polyethylene pots 18 cm x 18 cm x 12 cm. Infestation was induced in the nursery , between 1970-1972 , by placing the pots between rows of larch seedlings that had been severely attacked by the insect. This method insured that the parasite was transmitted to the grafted trees in a natural way. In order to further expose them to conditions favouring natural infestation the clones were outplanted on a 3 m x 3 m spacing in the autumn of 1972 at Sinaia , Toplita and Huedin. A randomised block design was used with 3 replications and 4 grafts per plot. Woolly aphid resistance was estimated at ages 11 and 19 on the basis of percent of injured needles. Due to some damage by deer , only 102 clones at two locations were suitable for measurements. Samples were collected at random from each tree when the attack was at its peak, i.e. in early July. Percentages were transformed into arcsin $\sqrt{\%}$ values , arranged according to the clone , replication , location and age , and statistically analysed. Three types of ANOVA were performed (Saulescu 1967, Nanson 1970) including:

- A 2-way (clones x replications) ANOVA performed separately on each location and on each age (Table 1) ;
- A 3-way (clones x replications x ages) ANOVA performed for each location (Table 2) ;
- A 4-way ANOVA (clones x replications x ages x locations) combined (Table 3) .

The significance of the differences was established by an F test and then by Duncan's (Duncan, 1955).

Standard errors (SE) of variance components were computed by the following formula (Anderson and Bancroft ; 1952) :

$$SE\sigma^2 = \sqrt{\frac{2}{K^2} \sum \frac{(MSg)^2}{f_g + 2}}$$

where : K= coefficient of the variance component; MS_g = the g - th mean square used to estimate the variance component ; f = degrees of freedom of the g - th mean square .

Broad-sense heritability estimates ($h^2{}_1$; $h^2{}_2$) were calculated by using variances obtained from the 3-way analyses (Formula 1 , Stern, 1967) and from the 4-way analyses (Formula 2, Stern, 1963) ANOVA, such as :

$$h^2{}_1 = \sigma^2{}_C \;/\; (\sigma^2{}_C + \sigma^2{}_{CA} / A + \sigma^2{}_e / RA) \qquad (1)$$
$$h^2{}_2 = \sigma^2{}_C \;/\; (\sigma^2{}_C + \sigma^2{}_{CL} / L + \sigma^2{}_{CA} / A + \sigma^2{}_{CLA} / LA + \sigma^2{}_e / LAR) \qquad (2)$$

where: C, L, A, R = clones , locations , ages and replications , respectively ;
$\sigma^2{}_C$, $\sigma^2{}_e$ = clones and error variances , respectively ;
$\sigma^2{}_{CL}$, $\sigma^2{}_{CA}$, $\sigma^2{}_{CLA}$ = C x L , C x A and C x L x A interaction variances ;

It must be stressed that only $h^2{}_1$, which was estimated by using variance for each specific location , is suitable in this example for a valid genetic gain calculation.

The genetic gain (Δ G) was calculated according to Falconer's (1960) formula:

$$\Delta G_1 = ih^2{}_1\sigma_p \quad ; \quad \Delta G_2 = ih^2{}_2\sigma_p \qquad (3)$$

where: i - intensity of selection and σ_p = phenotypic standard deviation.

RESULTS

Genetic variation

Strong differences ($p < 0.001$) among clones in resistance to woolly aphid existed in both plantings and at both ages (Table 4) . The same results were obtained by the combined ANOVA (Tables 5 and 6) . This suggests that the variation has a genetic background and that selection and breeding European larch for woolly aphid resistance / tolerance is possible .

There were significant ($p < 0.05$) (Table 6 , row 6) and highly significant ($p < 0.001$) (Table 5, row 4) differences among clones in their reaction to the two ages which demonstrated a clear clone x age , and suggests a parasite x age interaction, as well .

There were also highly significant differences ($p < 0.01$) among clones in their reaction to the ecological conditions at the two locations (Table 6, row 5) .This emphasises the strong interaction of clone x environment on the one hand , and the parasite x environment interaction, on the other. Nevertheless , one might conclude that resistance of clones is under genetic control even if their reactions to the environment are different .

The mean of the attacked needles at age 11 and 19 was 17.4 % and 12.6 % ,respectively , in the Sinaia planting , and 31.4 % and 19.4 % , respectively , at Toplita (Table 4) . It was evident that the woolly aphid attack intensity was variable from one location to another , and from age to age within the same location . The most severe attack occurred at age 11 at both sites and the heaviest attack was at Toplita . Therefore, the Toplita site at age 11 was the most suitable for testing the resistance of European larch clones to woolly aphid attack .

Duncan's multiple range test (Figure 1) , that took into account the data obtained from both 3- and 4-way ANOVA , demonstrated that:

- The 102 clones tested were distributed into 15 homogeneous groups in the Toplita trial and only 4 groups at Sinaia . The greatest variability of resistance occurred within the Toplita trial which suggested the true genetic values of the clones ;
- The woolly aphid resistance averaged 15.0 % at Sinaia (Table 5) where the most resistant clone had only 5.6 % attacked needles and the most susceptible clone had 28.8 % , i.e. a 414 % difference (Figure 1);
- The woolly aphid resistance averaged 25.7 % at Toplita (Table 5) where the most resistant clone had 6.2 % attacked needles and the most susceptible 39.6 % , i.e. a 539 % difference (Figure 1);

Figure 1 demonstrates that in general , the results obtained at Sinaia would not apply to Toplita , or to other areas with a similar environment . The ANOVA also indicated that enough individual genetic variation for resistance to the woolly aphid was found within clonal populations , and implicitly within initial larch populations , to be exploited in a breeding program .

Heritability

The broad-sense heritability estimates , calculated on the basis of the variances using the 3-way ANOVA were 0.379 at Sinaia and 0.811 at Toplita (Table 5) . The varying values of heritability between locations might be attributed to environmental conditions that influenced the evolution of the parasite .

The broad-sense heritability calculated from the variances from 4-way ANOVA was 0.449 (Table 6) . This value can not be used because of the multiple significant clone x location x age interactions that existed . Only local heritabilities can be used for expected genetic gain calculations . Therefore , woolly aphid resistance is a heritable trait but , in this case , only when the resistant larch clones are to be vegetatively propagated .

Corelations

Significant ($p < 0.05$) and highly significant ($p < 0.01$; $p < 0.001$) age to age , location to location and age to location phenotypic correlations were found among woolly aphid resistance values (Table 7) . These data showed that the resistance to the parasite was attributable to the same gene complex that operated on clone - parasite system in various environments.

Genetic control

The frequency distribution of woolly aphid resistance values in European larch clone populations illustrates a continuous variation which was very close to a normal distribution (Figure 2) . Such a pattern of variation was specific to quantitative traits that are polygenically controlled (Lerner, 1958 , Mather and Jinks, 1977) . The polygenic control is very important in larch breeding because it provides a horizontal resistance which, according to Vanderplank (1968) , is effective against all parasite races . Similar results were obtained with the same material at a younger age (Blada, 1982) .

Genetic gain

If the best 10 , 20 , 30 and 40 clones of the 102 tested were selected and planted in suitable environmental conditions , a genetic gain in resistance of 11.7 % , 9.4 % , 7.8 % , and 6.5 % , respectively , at Sinaia , and 31.6 % , 25.3 % , 21.0 % , and 17.5 % , at Toplita , could be achieved (Table 8) . The varying genetic gain by location might be attributed to the varying values of heritability magnitude and the degree of woolly aphid resistance variation within a location . The above mentioned genetic gains are only obtainable using vegetative propagation .

CONCLUSIONS

Enough individual genetic variation for woolly aphid resistance was found within clonal populations , and implicitly within natural populations , to be exploited in a breeding program .

Larch resistance to this pest is a continuously varying trait , i.e. under polygenic control .

Larch resistance to woolly aphid is a heritable trait and such traits can be improved

.

The breeding strategy should exploit all of the genetic variation . This is possible only by using vegetative propagation including somaclonal embryogenesis .

By selecting the most resistant larch clones , a significant genetic gain could be achieved .

In general, the results gathered at Sinaia would not apply to Toplita , or to other environments similar to those found at Toplita .

The latest results validate those obtained at younger ages using the same clones .

ACKNOWLEDGEMENTS

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Table 1. Model for two - way ANOVA

Source of variation	Df	MS	E(MS)
Total	CR - 1		
Replications (R)	R - 1	MS_R	$\sigma^2_e+C\sigma^2_R$
Cloners (C)	C - 1	MS_C	$\sigma^2_e+R\sigma^2_C$
Error (E)	(C - 1) (R - 1)	MS_E	σ^2_e

Table 2. Completly random model for 3 - way ANOVA

Source of variation	Df	MS	E(MS)	F-test
Total	CRA -1			
Replications (R)	RA - A	MS_R		
Cloners (C)	C - 1	MS_C	$\sigma^2_e+R\sigma^2_{CA}+RAL\sigma^2_C$	
Ages (A)	A - 1	MS_A	$\sigma^2_e+R\sigma^2_{CA}+RL\sigma^2_A$	
C x A	(C - 1) (A - 1)	MS_{CA}	$\sigma^2_e+R\sigma^2_{CA}$	
Error (E)	A (C - 1) (R - 1)	MS_E	σ^2_e	

<u>Parameters :</u>

$\sigma^2_e = MS_E$; $\sigma^2_C = (MS_C - MS_{CA})/RA$;

$\sigma^2_{CA} = (MS_{CA}-MS_E)/R$; $\sigma^2_p = \sigma^2_C + \sigma^2_{CA}/A + \sigma^2_e/RA$;

Table 3. Completly random model for 4 - way ANOVA

Source of variation	Df	MS	E(MS)
Replications (R)	RLA - LA	MS_R	
Ages (A)	A - 1	MS_A	$\sigma^2_e+ R\sigma^2_{CLA}+ RC\sigma^2_{LA}+RL\sigma^2_{CA}+ RLC\sigma^2_A$
Locations (L)	L - 1	MS_L	$\sigma^2_e+ R\sigma^2_{CLA}+ RC\sigma^2_{LA}+RA\sigma^2_{CL}+ RAC\sigma^2_L$
Cloners (C)	C - 1	MS_C	$\sigma^2_e+ R\sigma^2_{CLA}+ RL\sigma^2_{CA}+RA\sigma^2_{CL}+ RLA\sigma^2_C$
C x L	(C - 1) (L - 1)	MS_{CL}	$\sigma^2_e+ R\sigma^2_{CLA}+ RA\sigma^2_{CL}$
C x A	(C - 1) (A - 1)	MS_{CA}	$\sigma^2_e+ R\sigma^2_{CLA}+ RL\sigma^2_{CA}$
L x A	(L - 1) (A- 1)	MS_{LA}	$\sigma^2_e+ R\sigma^2_{CLA}+ RC\sigma^2_{LA}$
C x L x A	(C - 1)(L - 1) (A - 1)	MS_{CLA}	$\sigma^2_e+R\sigma^2_{CLA}$
Error (E)	LA (C - 1) (R - 1)	MS_E	σ^2_e

<u>Parameters :</u>

$\sigma^2_e = MS_E$; $\sigma^2_{CLA} = (MS_{CLA}-MS_E)/R$; $\sigma^2_{LA} = (MS_{LA}-MS_{CLA})/RC$;

$\sigma^2_{CA} = (MS_{CA}-MS_{CLA})/RL$; $\sigma^2_{CL} = (MS_{CL}-MS_{CLA})/RA$;

$\sigma^2_C = (MS_C - MS_{CL} - MS_{CA} + MS_{CLA})/RLA$;

$\sigma^2_p = \sigma^2_C + \sigma^2_{CL}/L + \sigma^2_{CA}/A + \sigma^2_{CLA}/LA + \sigma^2_e/LAR$;

<u>F-test :</u>

$F_R = MS_R/MS_{CLA}$; $F_{CL} = MS_{CL}/MS_{CLA}$;

$F_A = MS_A/[(MS_{CA}+MS_{LA})/2]$; $F_{CA} = MS_{CA}/MS_{CLA}$;

$F_L = MS_L/[(MS_{CL}+MS_{LA})/2]$; $F_{LA} = MS_{LA}/MS_{CLA}$;

$F_C = MS_C/[(MS_{CL}+MS_{CA})/2]$; $F_{CLA} = MS_{CLA}/MS_E$;

Table 4. Two - way ANOVA performed on locations and ages, separately

Source of variation	Df	Sinaia - 11[1]		Sinaia - 19[1]		Toplița - 11		Toplița - 19	
		MS	F	MS	F	MS	F	MS	F
Replications	2	37.88	1.20	34.75	1.15	237.90	4.01	192.47	4.91
Clones	101	110.62	3.52***	85.36	2.84***	315.77	5.30***	161.83	4.14***
Error	202	31.43		30.07		59.53		39.14	
Mean		17.4		12.6		31.4		19.9	

[1] Sinaia - 11 and Sinaia - 19, i. e. the data were taken at age 11 and 19, respectively ;

Table 5. Three - way ANOVA performed in each location for the two ages combined

Source of variation	Gl	Sinaia -11 + Sinaia -19		Toplița -11 + Toplița 19	
		MS	F	MS	F
Total	611				
Replications	4	36.32	0.46	265.20	5.38
Clones (C)	101	127.08	1.61***	401.60	5.29***
Ages (A)	1	3452.54	43.76***	20126.51	264.90***
C x A	101	78.90	2.57***	75.98	1.54***
Error (E)	404	30.75		49.34	

Parameters		
$\sigma^2_C \pm SE$	4.015 ± 1.640	27.130 ± 4.746
$\sigma^2_{CA} \pm SE$	8.025 ± 1.867	4.440 ± 1.857
$\sigma^2 e \pm SE$	30.750 ± 2.158	49.340 ± 3.463
σ^2_p	10.590	33.462
σ_p	3.254	5.785
x	15.0	25.7
h^2_1	0.379	0.811

x = the general mean for each location (at the 2 ages combined)

Table 6. Four - way ANOVA performed for all locations and ages combined

Source of variation	Df	MS	F - test
Replications (R)	8	150.75	1.85
Ages (A)	1	19890.00	10.50**
Locations (L)	1	34290.00	17.61***
Clones (C)	101	307.12	2.46***
C x L	101	130.60	1.60**
C x A	101	119.56	1.47*
L x A	1	3536.34	49.50***
C x L x A	101	81.30	2.03***
Error	808	40.04	

Parameters

σ^2_C = 2.880± 0.969	σ^2_{CLA} = 3.478± 0.958	σ_p = 2.565
σ^2_{CL} = 2.054± 0.893	σ^2_e = 40.040± 1.990	x = 20.3
σ^2_{CA} = 1.594± 0.839	$\sigma^2 p$ = 6.581	h^2_2 = 0.449

x = the general mean for all locations and ages,combined

Table 7. Age to age, location to location and age to location phenotypic correlations (Df=100)

	Sinaia - 11	Toplița - 11	Sinaia - 19	Toplița - 19
Sinaia - 11	1.000	0.315**	0.326**	0.244*
Toplița - 19		1.000	0.313**	0.343***
Sinaia - 11			1.000	0.201*
Toplița - 19				1.000
+ = $p < 0.05$; ++ = $p < 0.01$; +++ = $p < 0.001$;				

Table 8. Expected genetic gain (ΔG %) at clonal level that could be achieved in wooly aphid resistance

Location	Genetic gain if selected the best .... clones			
	10	20	30	40
Sinaia (S)	11.7	9.4	7.8	6.5
Toplița (T)	31.6	25.3	21.0	17.5
S x T combined	9.7	7.8	6.4	5.4

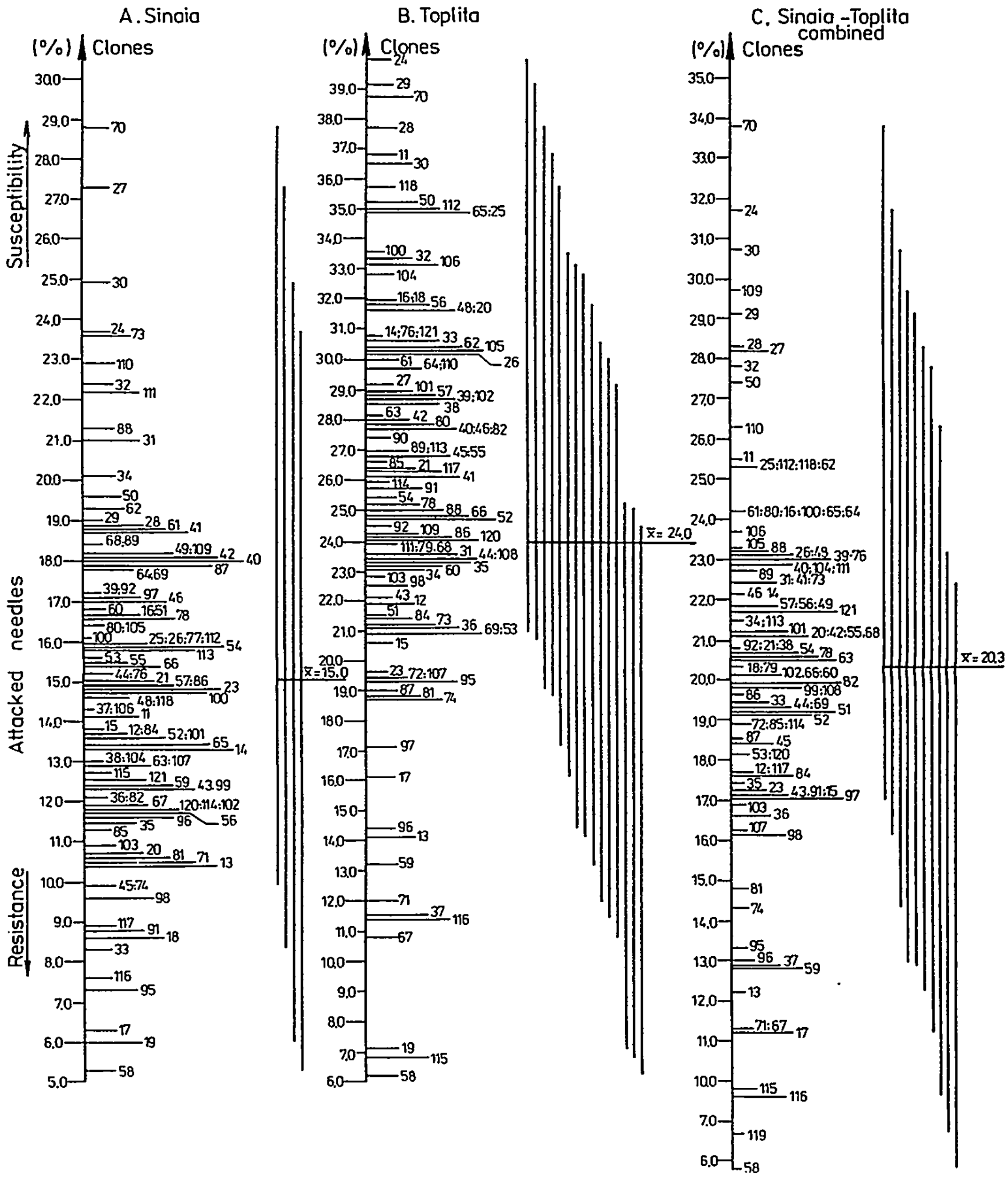

Figure 1. Distribution of the clones into homogeneous groups for the woolly aphid resistance according to DUNCAN test ($p < 0.05$)

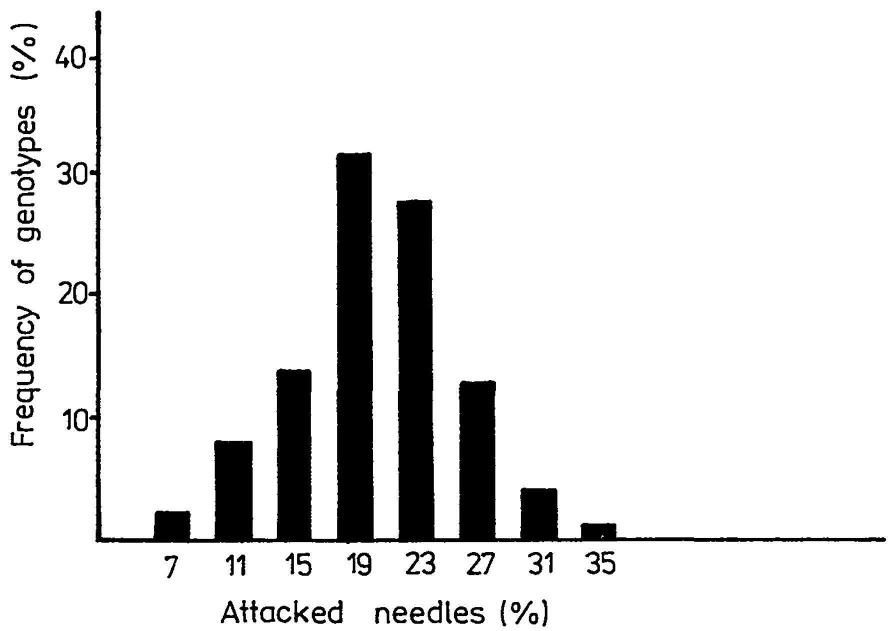

Figure 2. Frequency distribution in larch clonal population evaluated for woolly aphid resistance.

TISSUE CULTURE OF ADULT LARCH AS A TOOL FOR BREEDING PURPOSES

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Abstract

Aimed at the identical reproduction of genotypes which are considered superior different methods were tested to establish and to propagate tissue cultures from old larch trees (*L. decidua, L. kaempferi, L. sukaczewii, L. gmelinii, L. eurolepis*). Serial subcultures without phytohormones (shoot tip propagation) led to the establishment of clone lines. After ten subcultures propagation velocity, shoot morphology and rooting behavior were similar to juvenile plant material. Serial subcultures which included a cytokinin induction led to the formation of adventitious shoot clusters (adventitious bud propagation). Adventitious shoots derived from male flowers of one *L. kaempferi* clone could be propagated via shoot tip propagation. Micrografting of meristems in vitro resulted in a regained rooting capacity of green cuttings from micrografts. Combining these in vitro techniques offers now the possibility to propagate selected mature larch trees for different breeding purposes.

Key words: *Larix*, adventitious buds, micrografting, rejuvenation, serial propagation

1. Introduction

Micropropagation of mature trees is often, with some exceptions, more difficult than in vitro propagation of juvenile individuals. This is the case especially for those conifers used in larger scale by forestry. Foresters are most interested in such individuals which have proved their quality traits (performance, resistance) over longer time periods. Also for the different larch species there exists an interest to propagate selected adult trees. This includes trees selected in natural stands as well as hybrids which derived from former breeding experiments. There are some main obstacles preventing a successful in vitro propagation:

- it is difficult to establish a propagating tissue culture (organ culture)
- the propagation velocity is low (growth behavior and morphology are different from juvenile material)
- the rooting success and transfer to the soil is insufficient

Nevertheless it seems to be possible to overcome all these difficulties if tissue culture methods will be optimized to regain a rejuvenation of the plant material.

2. Plant material

The plant material included in the experiments were clones from *Larix decidua* (80 to 140-year-old), one clone of *L. kaempferi* (80-year-old) and ten clones of *L. eurolepis* (30-year-old) in cooperation with Dr. Weiser, Institute for Applied Forest Tree Breeding (Germany), clones of *Larix sukaczewii* (80 to 100-year-old; in cooperation with Dr. Puthenikhin, Botanical Garden Institute, Ufa, Bashkortostan) and one clone of *Larix gmelinii* (100-year old; in cooperation with Prof. Han, Forestry Academy, Beijing, China). Terminal parts of twigs (3 cm in length) harvested from late September to March were sterilized with 0.25% mercuric chloride for 5 minutes and rinsed three times with sterile destilled water. The buds and meristems used for experiments were excised with sterile scalpels.

3. Methods

3.1 Serial subcultures without phytohormones

The serial propagation of adult plant material (Fig. 1) was carried out by a method developed for the propagation of juvenile larch shoots in continuous red light (Hübl and Zoglauer 1991) with some modifications.

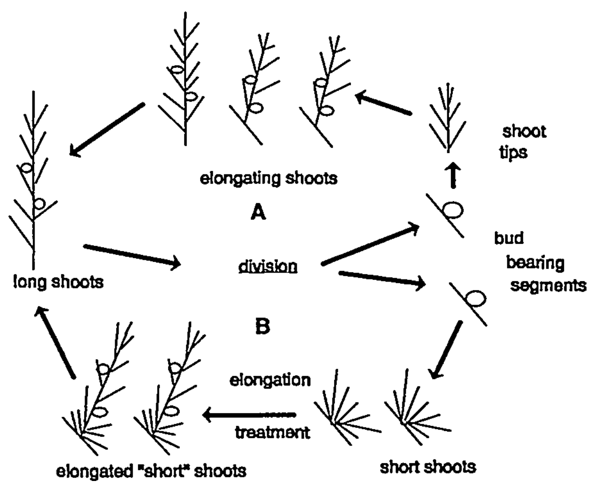


Figure 1
Serial subculture of larch shoots without phytohormones (A) including short shoot stimulation (B)

Terminal buds were excised and cultured on a half-strength medium according to Boulay(1979) with the addition of glutamine (146 mg l^{-1}) and 0.5% (w/v) activated charcoal for one 7-week-subculture. After this time the shoots were subcultured on the same medium without activated charcoal. Growing shoots were cut into shoot

tips and bud bearing stem segments which can sprout and form long shoots. The number of shoots and shoot segments was counted.
In some cases when short shoots were formed it was tried to stimulate their elongation by a combined treatment (cytokinins, light, temperature, Fig. 1 B) which was developed for juvenile larch (Kretzschmar 1993). The percentage of elongating short shoots was measured. Rooting of long shoots was achieved when shoots were induced with 2 mg l^{-1} naphthalene acetic acid (NAA) on a reduced nutrient medium according to Murashige and Skoog (1962). After 2 weeks the explants were placed into peat pellets and stored in little plastic greenhouses. After five months rooted shoots were counted.

3.2 Serial subcultures including phytohormones

3.2.1 Lateral buds

Excised lateral buds were cultured for 10 days on a medium containing activated charcoal (preculture). After this period buds were cultured on a half-strength MCM medium (Bornman 1983) with 100 mg l^{-1} arginine and 1.5 mg l^{-1} zeatin, 0.15 mg l^{-1} kinetin and 0.05 mg l^{-1} indolylbutyric acid (IBA) for 3 weeks. Clusters of adventitious buds developed on a medium without plant growth regulators (BEMB) containing macroelements used by von Arnold (LP -- 1981) with a reduced concentration of ammonium nitrate (2.5 mM = 200 mg l^{-1}). The microelement composition used was published by Boulay (1979). This medium was supplemented by addition of 100 mg l^{-1} polyvinylpyrrolidone (PVP). After 4 weeks the adventitious buds were counted, separated and induced in a new induction cycle on the cytokinin containing medium. All subcultures were carried out under continuous red light.

3.2.2 Male flowers

Male flowers from the adult tree of Japanese larch were harvested in March. They were sterilized, excised and subcultured on a basal medium (SPE) according to Gupta & Durzan (1987) containing 1 mg l^{-1} kinetin and 2 mg l^{-1} NAA. After one month the flowers were transferred to the induction medium MCM mentioned above (3.2.1) and subcultured as described there. Elongating adventitious buds were transferred to the medium according to Boulay (3.1) to support elongation and shoot tip propagation.

3.3 Micrografting in vitro as a pretreatment for later vegetative propagation in vitro and ex vitro

Seeds of European larch used as rootstock were sterilized and germinated on medium BEMB.
In these experiments (part I) buds from three 140-year-old trees of European larch were grafted lateral into the hypocotyl of three-month-old seedlings.

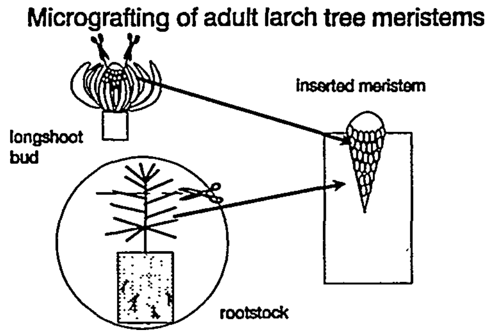


Figure 2

Rooted grafts were transferred to the soil, hardened and cultured in the greenhouse. In the following experiments (part II) sterilized seeds were transferred directly into autoclaved peat pellets under red light conditions for germination of rootstocks. Excised meristems of seven clones were grafted into the epicotyl (stem axis ; Fig.2) of this rootstock (Ewald, D; Kretzschmar, U.; Putenikhin, V.P.; Han Yifan 1994). Immediately after the grafting procedure grafts were kept in darkness for one week. After formation of the graft union and sprouting grafts were potted and transferred to little plastic greenhouses.

3.3.1 Vegetative propagation ex vitro

Three (part I) respectively two years (part II) after grafting lignified green cuttings were harvested from different micrografts of 7 *Larix decidua* clones, treated with a rooting paste containing 2g/l IBA as auxin and placed in peat pellets in little plastic greenhouses at 17°C. Ninety days later the cuttings with visible roots outside the peat pellet were counted.

3.3.2 In vitro propagation

To establish shoot cultures from a 3-year-old micrograft (*Larix decidua* LH30) shoots were harvested, sterilized and serial subcultured without phytohormones as already described. Buds harvested from the same adult donor tree (clone) were cultured under the same conditions to compare propagation rates.

4. Results

4.1 Serial subcultures without phytohormones

After establishment of terminal long shoot buds from different *Larix decidua* clones (140-year-old), characterized by slower shoot growth and an enhanced formation of short shoots, one clone (LH23) started free growth after ten subcultures or 70 weeks (Kretzschmar and Ewald 1994). Its growing capacity as well as the rooting ability improved with the number of subcultures until these parameters were comparable to juvenile plant material (Fig. 3). We realized the same improvement of physiological performances when we compared short shoot stimulation depending on the number of subcultures. After 13 culture cycles 46% of the tested short shoots turned into free growing long shoots as a result of the stimulation treatment (Table 1).
Fifty plants from this adult clone (LH23) produced by serial subcultures and rooting of the long shoots were already transferred to the soil and will be used for field trials as well as for investigations concerning morphological changes in relation to rejuvenation (branching and needle parameters).

Figure 3

Influence of serial subcultures on propagation and rooting behavior of one 140-year-old larch clone (*Larix decidua*)

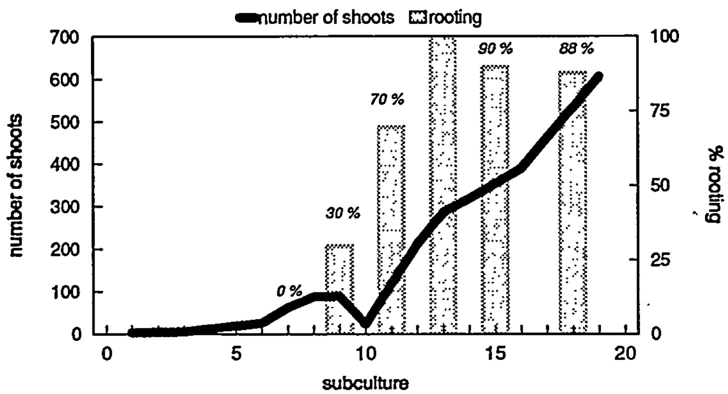


Table 1
Influence of continuous subculture of adult larch shoots on the success of a combined treatment (phytohormones; light/temperature-change) to stimulate the elongation of short shoots (*Larix decidua*;140-year-old clone LH23 ; N= 90)

no.of subcultures	2-3	4	5-7	8	9-10	11	12	13	14	15	16	17
elongation	0	4.2	0	12.5	0	48.5	50	n.t.	18	46	32.2	45

n.t. - not tested

Starting with ten selected hybrid larch trees (*L. eurolepis* - Weiser 1992) it was possible to establish propagating tissue cultures from 5 trees during a one-year-period. The development of culture behavior was similar to the very old clone LH23. Despite the restricted numbers of subcultures the clones have passed at present they.regained the ability to react on a short shoot stimulation to a certain amount, which is impossible for adult plant material during the first subculture cycles.

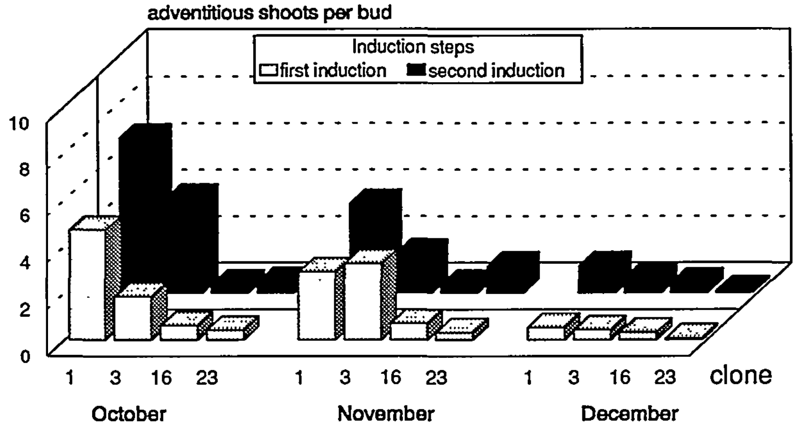
4.2 Serial subcultures including phytohormones

4.2.1 Lateral buds

Using the alternating induction scheme separable shoot buds were formed just after the first cycle. The choice of different basal media for induction and differentiation as well as the cytokinin combination used for repeated induction steps was similar to a system developed for Norway spruce (Ewald and Süß 1993).

Figure 4

Number of adventitious buds formed from dormant buds depending on clone, month of harvest and number of induction steps



Analogous to experiments without phytohormones the most effective time to start tissue culture was the early autumn (Fig. 4). Thus it was possible to subculture and to propagate these adventitious shoot clusters since the establishment up to now for 6 cycles (approximately one year).

4.2.1 Male flowers

The first induction with the cytokinin medium led to the formation of adventitious buds on the base of male flowers derived from a Japanese larch. These buds were induced repeatedly for more than one year until one shoot started elongation. This shoot was serial propagated (cf. point 3.1) on the medium according to Boulay to multiply this clone for rooting and plant regeneration.

4.3 Micrografting in vitro as a pretreatment for later vegetative propagation in vitro and ex vitro

The grafting system shown (Fig. 2) and the chosen vessel (Petri dish) allowed to carry out the grafting procedure quickly and without any disturbance of the rootstock. Different larch species tested formed graft unions and started long shoot development (Table 2). Like for other physiological performances (rooting, flowering) the grafting success was depending on the clone. After sprouting the micrografts showed a growth habit comparable to juvenile plants. The needles were longer and the distance between needles was wider than on the adult donor trees.

Grafting success of meristems from adult clones of different larch species 50 days after grafting on sterile Larix decidua seedlings

species	no. of clones tested	age of donor trees	no. of grafts	sprouting of meristem (%)
L. decidua	7	140	148	79,34
"	1	80	15	66,6
L. sukaczewii	3	80	29	46,7
L. gmelinii	1	100	17	70,6
L. kaempferi	1	80	15	53,3

Table 2

4.3.1 Vegetative propagation ex vitro

From 50 micrografts of seven *Larix decidua*-clones (140-year-old) 119 green cuttings in total were harvested for rooting experiments. Compared with cuttings from the adult donor trees, where no rooting occured, the rooting success was 47% on average.

4.3.2 In vitro propagation

From long shoots of one micrografted clone it was possible to establish a propagating line in vitro (serial subculture without phytohormones, Fig. 5).

Comparison of propagation behavior between adult explants vs. micrografted explants

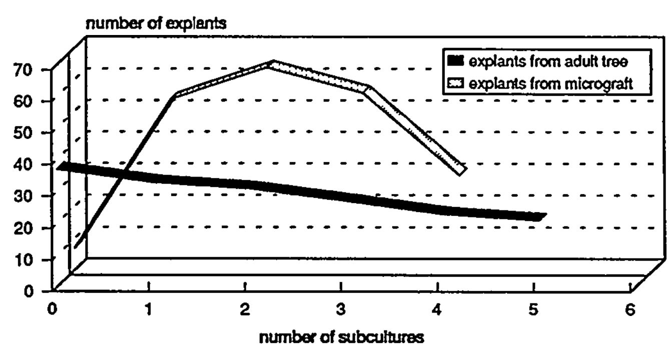


Figure 5

In comparison to that, buds established directly from the adult tree formed elongating shoots under the same conditions but the number of shoots diminished during the following propagation cycles because of short shoot formation and beginning of delayed growth.

Discussion

Different ways to establish plant material from adult donor trees into tissue culture were successful. Although the number of clone lines which can be propagated and regenerated to whole plants is yet restricted, an influence of serial propagation cycles was clearly demonstrated.

Growth habit and morphology of the shoots of clone LH23 as well as the five hybrid larch clones which started free growth during serial subculture in vitro were similar to shoot cultures of juvenile larch clones. The rooting ability of the adult larch LH 23 clone was restored by serial subcultures without phytohormones. The shoots rooted with a frequency of up to 100 % after 13 subcultures. This confirmed the positive influence of continuous optimal growing conditions on the improvement of organ formation. For five hybrid larch clones it is now possible to multiply shoots of this plants and to follow the rejuvenation process until they have reached an increased rooting capacity for plant production. With the cloned material available, which was different in age according to its physiological reactions, now an experimental background exists to look more in detail for the principles of maturation and rejuvenation. Useful morphological and biochemical markers (Fouret et al. 1986, Bon 1989, Greenwood et al. 1989, Takemoto and Greenwood 1993) have to be confirmed and selected to determine the degree of phase change.

Under the influence of alternating cytokinin treatments it was possible to stimulate lateral buds of a wider variety of larch clones to react and regenerate adventitious buds. The possibility to establish tissue cultures and to multiply organs from adult trees was however a necessity to study the influence of the subculture cycles on the elongation behavior as it was already done with shoot cultures. Adventitious buds from adult larch trees always formed short shoots in the first year of culture. The induction treatment chosen to form adventitous buds was in its basic principles (cytokinins, nutient media) similar to the procedure to stimulate short shoot elongation (Kretzschmar 1993) and did not prevent the elongation of adventitious buds formed from juvenile larch material. From experiments with adult plants of other species (*Sorbus aucuparia*, *Picea abies*) serial subcultured under the influence of cytokinins in our laboratory we concluded that results concerning a regained physiological potential (elongation, rooting) were not expectable before 1 year of culture (unpublished). The possibility to regain the elongation capacity from adventitious buds derived from male flowers of a Japanese larch after one year of subculture cycles confirms this assumption. Another possibility to influence plant material from adult trees was grafting on a juvenile rootstock. Grafting was known to cause phase reversion in woody plants which can be achieved by adjusting of small explants to optimal growth conditions (Misson and Giot-Wirgot 1985, Jonard 1985, Monteuuis 1987, Monteuuis 1991, Tranvan et al. 1991, Monteuuis and Dumas 1992). Vigorously growing juvenile rootstocks were able to

influence a very small part of an adult tree (meristem) via several metabolites including phytohormones (Monteuuis and Bon 1990). The miniaturization of the explant was one of the methods to exclude effects of surrounding tissues which often prevented morphological responses by correlative control (Trippi 1990, Bonga and von Aderkas 1991).
After formation of a graft union and elongation of the long shoot meristem a growth habit similar to juvenile larch trees was visible. As one of the most striking criteria of a rejuvenation was the evidence of a restored rooting competence has to be considered (Pliego-Alfaro and Murashige 1987). It was not possible in our experiments to root green cuttings of larch collected from the 140-year-old trees directely. The micrograft derived cuttings of two clones formed roots after an auxin treatment. The rooted plants were transferred to the greenhouse and started sprouting.
A tissue culture established from one older micrograft (LH30) showed an improved propagation behavior in comparison with plant material immediately established from the donor tree. Several experiments to establish a propagating shoot culture directly of this or other adult clones failed. It was possible for the first time to establish a propagating culture from a micrograft.
These results were the first encouraging hints to expect that a propagation of adult larch trees in a larger scale could be possible in the near future. Several possibilities to combine the developed methods are conceivable. Thus, it is possible to start serial subcultures without phytohormones from micrografts or from adventitious buds. Another way might be to graft adventitious buds to stimulate their elongation for a following serial subculture.
Summarizing the results we conclude that for several larch species possibilities exist to apply single tissue culture techniques or their combination to get rejuvenated plant material for vegetative or in vitro propagation. Such a plant material is recommendable for physiological experiments as to get more information about juvenility in forest trees. The ability to posses regeneration and propagation systems for selected adult larch trees offers now new possibilities for breeders to introduce this plant material in the breeding process. Field trials with theses plants in comparison with juvenile material will provide more facts about stability of the observed rejuvenation as well as about its performance.

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CONTRIBUTION TO THE IMPROVEMENT
OF SEED EXTRACTION IN LARCH

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SUMMARY

Industrial techniques in a seed plant resulted in the extraction of a small percentage of seed potential (18% in hybrid larch and 40% in European larch). It was determined that the seeds remaining within the cones were as viable as the seeds extracted. Thus, the quantity of marketable seeds was directly proportional to the quantity of seeds extracted and an important gain in seed yield could be achieved by improving extraction techniques.

Among the five techniques tested in a second experiment, the two cone grinding treatments, done in a hammer mill, were characterized by the best extraction rate (up to 80% of seed potential) but they resulted in a decrease in seed viability. However, cone grinding applied to large volume of cones produced highly viable seeds. The difference was attributed to the number of cones treated.

With regard to other techniques, cone drying followed by cone threshing was more efficient when it was applied to cones previously cut in two or let outside for a couple of months. All these techniques gave better results when cones were collected in spring rather than in autumn whereas cone grinding efficiency did not depend on cone collection date.

Keywords : seed extraction, cone grinding, seed orchard, Larix X eurolepis, Larix decidua.

INTRODUCTION

Among the main coniferous species used in afforestation in temperate countries, hybrid larch (*Larix x eurolepis* Henry) is probably the one which has the rarest and the most expensive seeds. Seeds are particularly hard to produce in French seed orchards because hybridization cannot occur naturally (Philippe and Valadon 1992). In this case, it is essential that all the links of the chain that results in hybrid seed commercialization (flower stimulation , pollen collection, pollen management, atificial pollination, control of insect pests, seed extraction) are fully efficient.

With regard to seed extraction, several authors pointed out that seeds of European larch (*Larix decidua* Mill.) are particularly hard to extract because the cones open with difficulty and the seeds are firmly fastened within the cones (Aldhous 1972, Gordon 1992). For recalcitrant species, specific techniques have been suggested like prolonged tumbling in a revolving drum (Gordon 1992), use of a potato peeling machine, of a tumbler equipped with saw webs (Willan 1992), grinding the cones lightly in a hammer mill (Gordon 1992, Willan 1992), soaking dried cones in hot or cold water followed by rekilning (Hall 1985, Gordon 1992). The last treatment can be done simply, like in Denmark. After a first standard extraction, cones are put sometimes in gunny bags and left outside for several months. Variations of temperature and humidity favours cone opening and the greatest part of the yield is obtained at the second extraction which takes place in the end of summer (Knudsen, personal communication).

The experiments described in this paper had two objectives: i) to quantify seed losses in industrial extraction in a French seed plant and ii) to compare the efficiency of five extraction techniques when cones were collected in autumn or spring.

MATERIAL AND METHODS

1st experiment : Estimating the efficiency of industrial extraction

Origin of the cones

The cones used in this experiment originated from the 1992/93 crop of two French seed orchards: a hybridization s. o. and a European larch s. o.

Hybridization seed orchard

This small unit (0.5 ha), established in Les Barres estate (centre of France) in 1976, includes clones of Danish origin (FH 201 hybrid formula). It consists of rows of one European larch clone (coded V 44) used as maternal parent alternating with rows of Japanese larch clones used for pollen production. In this seed orchard, hybridization can not occur naturally because the two species do not flower at the same time. In 1992, very good flowering year, 120 grafts of European larch were pollinated artificially for hybrid seed production. Cones were harvested in September 1992.

European larch seed orchard

This seed orchard was established in 1985 in « Le Theil », in the Southwestern part of France. Total area is 13 ha. It includes 179 clones of Sudetes origin. The first crop (6 hl) occurred in 1992/93.

<u>Description of the work</u>

In a first step, work has been achieved at Vilmorin Company seed plant, then at Cemagref lab. Experimental protocols were the same for hybrid larch and European larch.

Determination of the crop characteristics

- measurement of the volume of cones treated at Vilmorin seed plant
- assessment of the number of cones treated by counting the number of cones in one sample of 5 liters per hl
- determination of the seed potential by multiplying by 2 the number of fertile scales counted in a sample of 50 cones.

Analysis of the product obtained after industrial extraction

- seed extraction in Vilmorin seed plant. Cones have been put, in a single layer, in the drawers of a fuel oil heated kiln (10 hl in capacity) and dried for 30 hours at 40°C before being tumbled in a perforated revolving drum (octagonal, 3 m long, 60 cm wide, 120 revolutions/mn, continuous feeding) which allows the seeds to fall through the perforations.
- rough product analysis
  . assessment of the number of extracted seeds according to raw product weight and number of seeds counted in 10 samples of 2 g
  . determination of full seeds percentage by cutting 10 samples of 50 seeds

Analysis of the seeds remaining within the cones after industrial extraction

- Previous trials had shown that cone grinding led to the extraction of almost all the seeds. So, samples of cones recovered at the end of the industrial extraction were submitted to this treatment, in a hammer mill (Electra, type Baby) designed for cereal crushing (figure 1). In this technique, the cones, poured into a loading funnel, fall into the rotor cavity (25 cm in diameter) where they are ground by 6 rotating hammers (1500 revolutions / minute). Finally, the seeds mixed with fragments of cones fall through the holes of the grating (8 mm in diameter) situated at the base of the rotor cavity and they are recovered in a hopper fixed below the grating. This treatment was applied to 5 replications of 400 cones.
- rough separation of seeds and waste by granulometry
- estimate of the number of extracted seeds per replication, based on total weight and number of seeds in 10 samples of 1 g
- determination of full seed percentage by cutting 8 samples of 50 seeds per replication.

2nd experiment : comparison of 5 extraction techniques and evaluation of the effect of cone collection date on seed extraction efficiency

<u>Origin of the cones</u>

The cones used in this experiment originated from the 1992/93 crop of Les Barres estate hybridization seed orchard (see 1.1 for description). They have been collected from two ramets of the European larch clone « V 44 », selected for three criteria : heavy cone production, full seed percentage and cone size nearly equal to the seed orchard average.

Treatments

Two factors were studied : the seed extraction technique and the cone collection date. Each of the 10 treatments (5 techniques * 2 dates) were applied to 250 cones.

Seed extraction technique

1) cone drying (40°C during 30 hours in an oven) + threshing against the ground of the bags containing the cones
2) method inspired from a Danish technique. The cones, put in gunny bags, were let outside for two months in May and June 1993 before being treated as in treatment 1
3) treatment 1 applied to cones previously cut in two (lengthwise section)
4) cone grinding in the cereal crusher described in experiment 1 (grating holes diameter : 20 mm)
5) more severe cone grinding (grating holes diameter : 8 mm).

Cone collection date

On the two grafts included in the experiment, half of the cones was harvested in September 1992, at the time of the commercial harvest of the seed orchard. At this date, cone scales were only slightly open. The remaining half of the cones was collected in the end of March 1993 when the cone scales were sufficiently open to allow the first seeds to be shed. At each collection date, cones of the two grafts were gathered and carefully mixed.

Description of the work

- determination of the seed potential. This analysis was achieved in two steps:
  . study of the relationship between the number of fertile scales and cone length (on a sample of 50 cones)
  . determination of the seed potential on the basis of the average length of a sample of 250 cones and the equation of linear regression.
- seed extraction
- assessment of the number of seeds extracted, based on total weight of raw product (seeds and waste) and on the number of seeds counted in 4 to 17 samples of 1 g (number of samples depending on the weight of raw product extracted)
- determination of the full seed percentage by cutting 10 samples of 50 seeds per treatment
- seed viability analysis. 1500 seeds (full and empty seeds mixed) were germinated without prechilling, on filter paper, in an incubator set at an alternating temperature of 30°C (8 hours) and 20°C (16 hours). Light was provided during the high temperature period. Germinated seeds were counted and removed every other day from day 6th to day 17th. After 17 days of incubation, all the non germinated seeds were cut in order to determine the number of full seeds that did not germinate. Germination rate was calculated as the number of germinated seeds * 100 / total number of full seeds.
- comparison of the germination capacity of seeds regarded as easy and hard to extract. All the seeds were carefully extracted from a sample of 20 cones and seeds originating from the apical, median (regarded as the easiest to extract) and proximal part of the cones (considered the hardest to extract) were germinated. The germination assay concerned 130 full seeds for each part of the cones.

Practical application

At the end of the two above-mentioned experiments, the remainder of the cones of hybrid larch that had already been submitted to industrial extraction at Vilmorin seed plant (3 hl) was treated in two steps: i) first cone grinding (cone grinding 1) with 20 mm grating holes and, after removal of the so-extracted seeds, ii) the cones underwent a more severe grinding (cone grinding 2) with 14 mm grating holes. Seeds originating from the two extractions have been kept separate until germination capacity was known.

Efficiency of the two treatments was determined from the quantity of seeds commercialized and seed viability.

Seed viability was determined in June 1994, after one year storage. Environmental conditions of the germination assay (incubator, temperature, light, ...) were the same as in the 2nd experiment. The assay included 200 full seeds, split in 4 replications, for each of the 4 following seed lots: i) 1st commercial lot (extraction in seed plant), ii) seeds originating from cone grinding 1, iii) seeds originating from cone grinding 2 and iv) 2nd commercial lot made of a mixture of seeds extracted by cone grinding 1 and 2.

Data analysis

- 95% confidence interval of the total number of seeds in a population weighing X grammes was calculated from the number of seeds counted in n samples of x grammes (Scherrer, 1984):

$$N = (m\,X / x) \pm 1.96\,(X / x)\ \left((1 - r)\,v / n\right)^{0.5}$$

where : N : 95% confidence interval of the total number of seeds in the population

m : average number of seeds in the samples

n : number of samples

r : sampling rate ($r = n\,x / X$)

v : variance of the number of seeds counted in the samples

- In experiment 2, full seed percentages were compared by 2 factor - ANOVA (extraction technique, cone collection date) after verification of the basic hypothesis (distribution, variance) and by Tukey test.

- Germination rates were compared by X^2 test to determine treatment effect and by the paired-sample method (Snedecor and Cochran, 1957) to test the effect of cone collection date.

RESULTS

Experiment 1

Cone size - number of treated cones

The two seed orchards produced cones of similar size (121 cones / hl) and, for both species, differences between replications were very limited. The numbers of cones per hl were higher than the average (Gordon, 1992). With regard to the hybridization seed orchard, the small size of the cones was attributed to the fact that cone production was very heavy in 1992/93.

On the whole, 3.3 hl of cones of hybrid larch (HL) and 6 hl of cones of European larch (EL) were treated in Vilmorin seed plant. This corresponded to 40000 and 73000 cones respectively.

Seed potential

The number of fertile scales averaged 41.5 and 40.5 for HL and EL respectively. As each fertile scale bears two ovules at its base, seed potential was estimated at 83 and 81 seeds per cone for these two species.

Analysis of the product obtained at the end of industrial extraction

Extraction at Vilmorin seed plant resulted in the production of 5.4 kg (HL) and 14.0 kg (EL) of raw product made of winged seeds and waste. On the average, the samples of raw product analysed for HL and EL contained 109 and 167 seeds per gramme respectively. For both species, coefficient of variation (standard deviation / average) was 15%. The quantity of seeds extracted per cone was estimated at 15 (13 < < 16 confidence interval at 5% level) for HL and 32 (28 < < 36) for EL. These figures corresponded to 18% and 40% of the seed potential respectively.

Full seed percentage reached 21% (HL) and 9% (EL). For HL, 20-25% full seeds is a normal ratio in this seed orchard after artificial mass pollination. Concerning EL, the high proportion of empty seeds was attributed to poor pollination related to the young age of the orchard.

Analysis of the product originating from the 2nd extraction

The second extraction, done by cone grinding, resulted in the recovery of 51 and 42 additional seeds per cone (*i.e.* 62% and 52% of seed potential) for HL and EL respectively. For both species no significant difference was found between the replications. 95% confidence intervals were 48-54 and 40-44 seeds per cone for HL and EL respectively. Moreover, full seed percentage was estimated at 21% for HL and 6% for EL.

Main results obtained in experiment 1 can be summarized as follows (table 1).

Table 1- Summary of the results obtained in experiment 1

	Hybrid larch	European larch
Crop Characteristics		
Volume of cones	3.3 hl	6.0 hl
Nb of cones / hl	12100	12100
Nb of treated cones	40000	73000
Seed potential (nb seeds / cone)	83	81
Industrial extraction		
Weight of raw product	5.4 kg	14.0 kg
Nb of seeds extracted / cone	15 (18% seed potential)	32 (40% seed potential)
Full seed %	21 %	9 %
2nd extraction		
Nb of seeds extracted / cone	51	42
Full seed %	21 %	6 %

Experiment 2

Seed potential

Cone length was comprised between 23 and 39 mm. In this interval, the number of fertile scales proved to be highly correlated with cone length (r^2= 0.77, $P < 10^{-3}$). The equation of linear regression was : $y = 1.51\ x - 0.48$ (where y represents the number of fertile scales and x the cone length in mm). Taking into account this equation and the average cone length of a sample of cones, seed potential was estimated at 91 seeds per cone.

Number of extracted seeds (table 2)

Whatever the date of cone collection, there was no overlap between the confidence intervals of the number of extracted seeds per cone for the 5 treatments. Therefore, all the treatments differed significantly. In both cases cone grinding proved to be the most efficient technique, especially the most severe one (8 mm grating holes). However the differences between treatments were smaller when the cones were collected in Spring because, contrary to cone grinding, the other techniques led to better extraction when cone harvesting was postponed to March.

Full seed percentage (table 2)

2 factor - ANOVA showed that the effects of treatment and cone collection date were not significant (P = 0.18 and P = 0.26 respectively). This result indicates that % of full seeds did not depend on the number of extracted seeds. In addition, treatment * date interaction was very low (P = 0.78).

Germination capacity (table 2)

No significant difference was found between the two dates of cone collection. On the other hand, one observed a highly significant effect of the extraction technique. Cone drying + threshing, the Danish method and, to a smaller extent, extraction from cones previously cut in two resulted in high germination rates (higher than 90%) whereas cone grinding was characterized by smaller germination rate. Furthermore, the more violent the grinding, the lower the seed viability (63% and 40% for treatments 4 and 5 respectively).

In addition, the seeds extracted from different parts of the cones had similar germination capacity. Percentages of viable seeds were excellent (96%, 98%, 98% for the seeds originating from apical, median and basal parts of the cones respectively).

Main results obtained in experiment 2 are shown in table 2.

Table 2- Summary of the results obtained in experiment 2

Treatment	Nb of seeds extracted / cone		% full seeds	Germination rate	Nb viable seeds extracted / cone	
	Sept.	March			Sept.	March
Drying + threshing	6 (a)	29 (a)	24	98 (d)	1.3	7.0
Danish method	20 (b)	33 (b)	23	97 (d)	4.7	7.2
Cones cut in two	27 (c)	37 (c)	20	90 (c)	4.5	7.1
Grinding (20 mm)	45 (d)	50 (d)	23	62 (b)	6.1	8.1
Grinding (8 mm)	72 (e)	74 (e)	24	40 (a)	6.0	8.2

In each column, values followed by the same letters do not differ significantly at 5% level

Practical application

Seed quantity

Large scale cone grinding applied to 3 hl of cones that had been submitted first to industrial extraction allowed recovery of 2.5 kg of additional seeds. Cone grinding 1 (20 mm grating holes) and cone grinding 2 (8 mm) produced 1.5 kg (78% full seeds) and 1.0 kg (70% full seeds) respectively. This represented about two times the quantity of full seeds commercialized after the industrial extraction (first commercial seed lot).

Seed quality

Before storage

Analysis done at Vilmorin Company indicated that germination rates of the two seed lots originating from cone grinding 1 and 2 were correct and similar to the germination rate of the first commercial lot. Therefore, these two seed lots were mixed and commercialized (2nd commercial seed lot).

After one year storage

Differences between the first and second commercial lots and samples of seeds originating from cone grinding 1 and 2 were not significant. Germination rates reached 87%, 85%, 88% and 82% respectively.

DISCUSSION - CONCLUSION

Experiment 1 clearly showed that the extraction carried out in 1992/93 at Vilmorin seed plant was far from complete. The amounts of seeds extracted represented only 18% and 40% of estimated seed potential for HL and EL respectively. Such low yields are not isolated instances. Data provided by the two other French companies that shared the 1992/93 crop of the hybridization seed orchard indicate that they commercialized 30000 and 96000 full seeds / hl respectively whereas Vilmorin ranked in an intermediate place with 50000 full seeds commercialized / hl. Even the best yield represented less than half the potential (estimated at 210000 full seeds / hl). In this respect, it should be stressed that French seed merchants have little experience of seed extraction in larch, quantities of cones treated in France being limited. Obviously, the standard technique they use proves to be ill-adapted to larch.

Moreover, two facts should be pointed out :

- Comparison of the amounts of seeds extracted per cone in the two seed orchards confirms that seeds of the clone V44, used as maternal parent in French seed orchards, are particularly difficult to extract.
- In experiment 1, the products of industrial extraction and subsequent cone grinding were characterized by similar full seed percentage and experiment 2 confirmed that the proportion of full seeds did not depend on the number of seeds extracted. In addition, germination assay carried out on seeds originating from different parts of the cones indicated that almost all the full seeds were viable, whatever their position in the cone. These results prove that the quantity of marketable seeds is directly proportional to the quantity of extracted seeds. They are in opposition to an accepted idea which has it that non extracted seeds are empty or non viable.

Taking into account the efforts devoted to hybrid larch seed production in France, as large seed losses as those found in experiment 1 are not acceptable. Seed merchants, as well as seed orchard managers, are convinced that improvement in seed extraction is urgently needed. They take an active part in the current research in that field.

Experiment 2 showed that other methods can give better results than the standard treatment. However, the efficiency of some of them depended on cone collection date.

When cones were harvested in September, as it is the case in French seed orchards, the two cone grinding treatments were by far the best techniques as regards the number of extracted seeds. In particular, the most severe one resulted in the extraction of nearly 80% of the seed potential. Moreover, the efficiency of cone drying + threshing proved to be significantly improved when it was applied to halves of cones or cones previously let outside for two months.

When cone collection was delayed until spring, the 5 treatments ranked in the same way but differences between treatments were smaller. This is due to the fact that the 3 drying + threshing treatments gave better results whereas cone grinding efficiency did not depend on cone collection date and, thus, on the extent of cone opening.

With regard to seed viability, the extraction techniques can be classed in two groups: those done by cone drying + threshing that produced highly viable seeds and the two cone grinding treatments characterized by lower germination rates. In addition, the most severe grinding which resulted in the best extraction was also the most detrimental to seed quality. As seeds regarded as the hardest to extract were as viable as the seeds considered the easiest to extract and as more of 98% of the full seeds germinated, the low viability observed for cone grinding cannot be attributed to the fact that this technique leads to the extraction of a greater number of seeds. On the contrary, it can be ascribed to the treatment itself. Binocular inspection having shown microfissures on some seeds, the loss in viability may be due to seed coat injuries.

In spite of rather low germination rates, the two cone grinding treatments proved to be the best techniques in that they allowed extraction of the highest number of viable seeds. If their interest appears questionable in the case of spring cone collection, their superiority was clear when cones were harvested in autumn.

Considering the results of experiment 2, it was to be feared that seed lots extracted by cone grinding could not reach the minimum threshold of viability (40% germination rate) demanded by French legislation for commercialization of hybrid larch seeds. This is the reason why the cones recovered after industrial extraction have not been submitted to the most severe cone grinding. Nevertheless, cone grinding 1 and 2 applied to these cones, that would have normally been thrown away, resulted in the commercialization of 1.5 time the quantity of seeds (and 2 times the quantity of full seeds) extracted at Vilmorin seed plant.

The most interesting point in these large scale cone grinding is that they produced seeds of high quality. This is not consistent with the results obtained in experiment 2. The difference may be due to the volume of cones that is treated. When few cones are ground, some of them leap and rebound for a long time in the rotor cavity before being ejected. On the other hand, when the hammer mill is full of cones, they may be ground faster and one can conceive that, in that case, damage are greatly reduced.

Taking into account these discordant results, it seems premature to conclude. Next experiments will attempt to determine without ambiguity the effect of this kind of cone grinding on seed viability. If it proves to be actually detrimental to seed quality, it would be necessary to modify the shape of the hammers or the revolution speed. In this respect the hammer mill described by Willan (1992) runs at lower speed (250 - 800 revolutions / minute) than the one used in our experiments in order to avoid seed injury. Moreover, the treatment inspired from Danish technique gave promising results. Genuine Danish method is certainly worth being tested in the future. Furthermore, as « soft » techniques (cone drying + threshing) were more efficient when cones were harvested in spring, it would be profitable to postpone cone collection until the cone scales are sufficiently open to allow the first seeds to be shed. However, this would demand very careful monitoring of the seed orchards and quick harvesting since cones can open rapidly and one runs the risk of losing a great part of the crop.

ACKNOWLEDGMENTS

This study received a financial support from European Union in the framework of the AIR programme CT 920143 « Northern Conifers in Fast Growing Conditions ». The author wish to thank JM Pommier for its technical assistance in field work.

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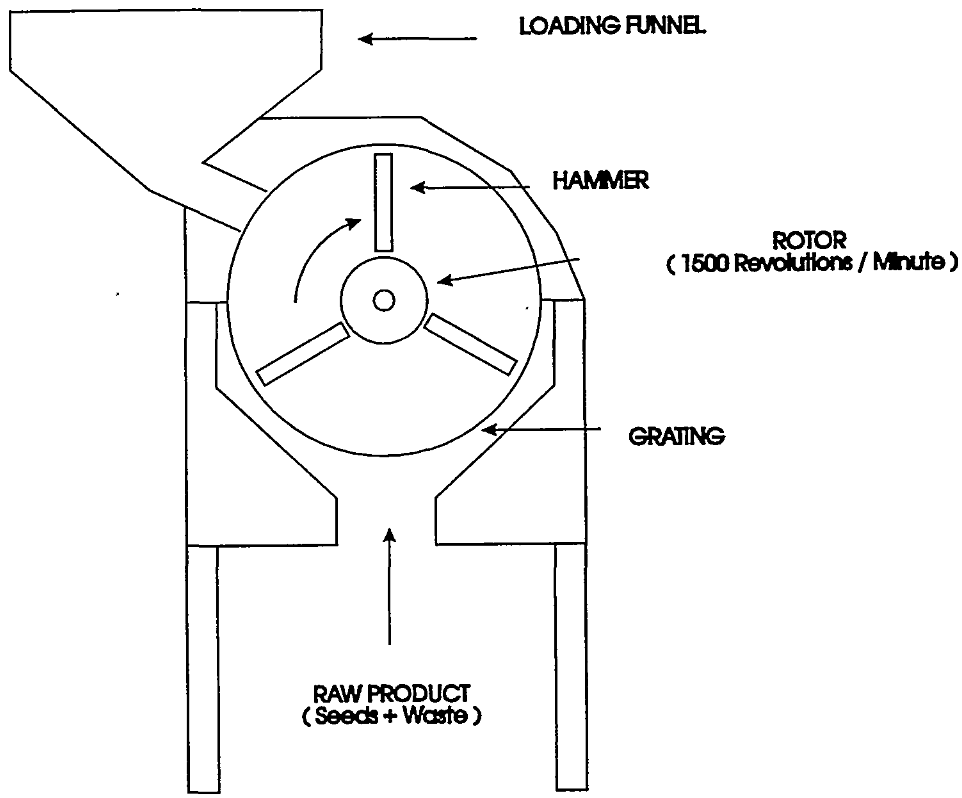
Figure 1.HAMMER MILL



Crookedness in Larch : apparition at the juvenile stage of stem form defects in relation to the annual shoot growth pattern

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Abstract

In order to clarify the unfavourable relationship between height growth and crookedness in European Larch, the elongation pattern of terminal shoot and the setting of stem defects were precisely described in 1994 in a 4-year-old progeny test. The dynamics of the lignification process was also studied through periodical measurements of the brown lignified part of the elongating shoot.

The evolution with time of the crookedness score of the elongating shoot showed that major defects appeared mid-August when more than 50% of the shoot was elongated. After this date, differences between the 20 open-pollinated progenies originating from Central Poland increased until the end of the growing season.

At the phenotypic level, significant differences between groups of individuals with extreme scores for shoot crookedness could be observed not only for the components of the elongation curve but also for the timing between the elongation and the lignification processes. Plants with the best form score distinguished themselves by an early start of elongation quickly followed by the beginning of lignification, and by a moderate maximum growth rate better adjusted to the lignification rate.

At the genotypic level, the progenies with extreme frequencies of crooked plants are particularly well discriminated in a canonical plane explained by the timing of the elongation and lignification processes and by the relative lignification rate compared to the maximum growth rate. Nevertheless, the intermediate crookedness score of most of the progenies is not entirely explained by the components of the shoot growth pattern.

The potential role of growth components in the setting of stem form defects of European Larch has to be confirmed both on a multisite and on a multiannual scale. In the same way, further investigations on qualitative aspects of the lignification process and on the mechanical effect of branching habit are now needed.

SOME CHARACTERISTICS OF JAPANESE LARCH ISOLATED AT A NORTHERNMOST POINT

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ABSTRACT

Northernmost point of the natural distribution of Japanese larch (*Larix kaempferi*) is considered as Mt. Manokamidake. It is at a distance of approximately 300 km from the center of the natural distribution of Japanese larch. In this mountain, 30 survival trees were found out in 1932.

However, the number of survival trees decreased and became only 12 in 1990 with an investigation after that. In this stand, because there are a few seedlings, an extermination of this population is worried about.

This Mt. Manokamidake population becomes one of provenances of Japanese larch provenance trials, and scions of this population were sent to Germany for international provenance trials.

Some characteristics of individual trees of Mt. Manokamidake differ from another Japanese larch. As I compared it with a standard Japanese larch, for example, the length of cone is short, the number of seminiferous scale of cone is small, and then opening time of winter buds is early. From these characteristics, it is thought that Manokamidake larch is very resembles Kuril larch (*Larix gmelinii*).

However, it is considered that Manokamidake population is genetically near Japanese larch with research depending on a current DNA analysis.

Keywords: Japanese larch, provenance trial, Mt.Manokamidake

SEED-CONE INITIATION ON SHORT SHOOTS AND LONG SHOOTS OF *LARIX LARICINA*

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SUMMARY

Vigorous young *Larix laricina* (Du Roi) K.Koch produce their first seed cones in lateral positions on long shoots in the upper crown. Subsequently, seed-cone bearing shifts more to terminal positions on short shoots. To enhance, or understand seed-cone development, knowledge of timing of cone initiation is important. Study of such timing is difficult because responsible apical meristems produce leaf primordia before bract primordia, so early activity corresponds to that in developing short- or long-shoot buds. Positional patterning of cones was used as a basis for study on 8-year-old trees. Developing buds were collected weekly, 9 July to 3 September, from proximal, medial, and distal positions on elongating long shoots in nine positions on lateral branches of the last 4 years, and from terminal positions on 1-year-old short shoots in proximal, medial, and distal positions on their respective 2-year-old long shoots in five positions on similar branches. Stained longitudinal sections of buds were photographed using a macroscope, and bud-component parameters measured on resulting prints at standard magnification. Buds terminating short shoots developed similarly at first, and leaf primordia began to form from mid-July. The first bract primordia, indicating seed-cone formation, were evident, on distal or medial short shoots, in mid-August. However, width of apex and of pith below the apex, and height of bud were greater, and relative height of the budscale-bearing receptacle and angle of leaf primordia were smaller in presumptive seed-cone than in short-shoot buds 1 to 2 weeks earlier. Lateral-bud development progressed acropetally. Presumptive lateral seed-cone buds in proximal positions were distinguishable using component measurements in early to mid-August, but bract primordia were not evident until late August. In mid-August, many distal lateral buds were distinguishable as long-shoot buds by extreme width of apex and pith below the apex. In these, at the end of August, axial-leaf primordia began to form on the flanks of a rising conical apex. At that time, a rising conical apex also occurred in seed-cone buds, but basal leaves were carried on a broad descending tissue to the budscale receptacle, rather than an ascending one.

Keywords: bud development, *Larix laricina* (tamarack), phenology, reproduction, seed-cone differentiation.

10 April 1995

PHYLOGENETIC STUDIES ON EAST ASIAN LARIX SPECIES USING RANDOM AMPLIFIED POLYMORPHIC DNA (RAPD) AND RBCL SEQUENCE

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Phylogenetic relationships of East Asian *Larix*

RAPD analysis was adopted to clarify the phylogenetical relationship among 4 species (*L. Kaempferi*, *L. gmelinii*, *L. gmelinii* var.*japonica*, *L. gmelinii* var.*olgensis*, *L. decidua*) of *Larix* distributed in East Asia. *L. decidua* was analyzed as an outer group. A dendrogram among 5 *Larix* species was presented on the basis of 93 loci data from RAPD analysis.

Among these 5 species, *L. decidua* was most distantly related to remaining 4 East Asian species. Mother species and two varieties of *L. gmelinii* gathered into one group.

Genetical differentiation among two strains of *L. gmelinii* var.*japonica*

L. gmelinii var.*japonica* is classified into 2 strains from morphological characteristics. One distributed in Sakhalin (*Karafuto-kei*), and another in Kuril'skie Ova.(*Chishima-kei*).

The result of RAPD analysis confirmed that the difference between the two strains of *L. gmelinii* var.*japonica* was caused by genetical differentiation.

Is Larix of Mt. Manokamidake in Japan classified as *L. Kaempferi* or *L. gmelinii* var. *japonica*?

Mt. Manokamidake is located at the northern boundary of the distribution of *L. Kaempferi*. Many botanists, however, propose that the *Larix* should be classed into *L. gmelinii* var. *japonica*, because it resembles *L. gmelinii* var. *japonica* in the morphological characteristics.

The phylogenetical study of Larix distributed in Mt. Manokamidake was done using RAPD method and *rbc*L sequence. As a result, it became clear that *Larix* of Mt. Manokamidake belonged to *L. Kaempferi*. The genetic composition was much different from that in the central mountains area in Japan. From these results, the *Larix* of Mt. Manokamidake should be classified as a variety of *L. Kaempferi*.

LARCH SEED ORCHARDS IN SWEDEN

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Background

The interest in larch has varied a lot from time to time in Sweden. European larch was introduced in the middle of the 1800' th century. At the end of the 1900' th century large quantatities of Sibirian larch seed was imported and used in central and northern Sweden. The peak of interest was reached during 1890's, 1930's, 1950's and 1960's. Today the interest in larch is slowly increasing.

Data about the seed orchards

During 1956 - 1964 a total of 21 seed orchards were established (see figure). This confirms the large interest in larch at that time. The orchards were based on selected plus trees from Swedish, Finnish and Danish trials and plantations. The knowledge of the origin of the plus trees is often poor. Probably most of the L. decidua clones are from the alp regions and Poland. These provenances have shown good production and quality in Swedish and Danish field tests.

Design

All Swedish hybrid seed orchards contain a number of father clones and one mother clone (mostly L. kaempferi). By collecting cones only from this self-sterile mother clone, production of 100 % hybrid seed is assured.

Seed harvest

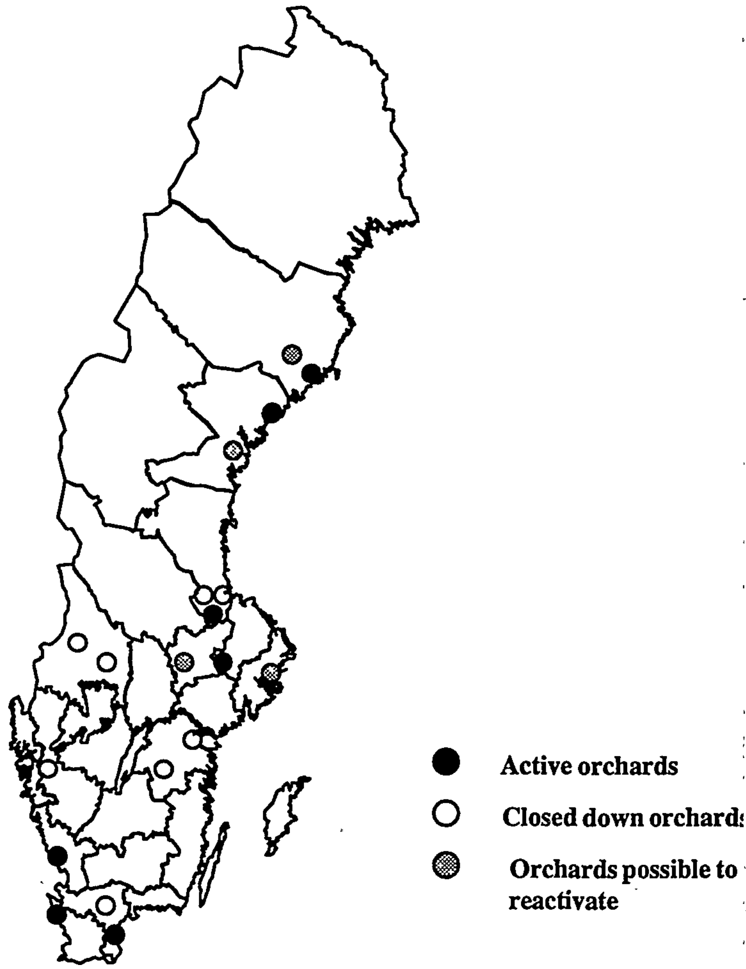
Today 7 of the 21 orchards are still active seed producers (see table). Besides, a new L. eurolepis elite seed orchard was established in 1992, consisting of the best progeny tested Swedish and Danish clones and another one will be established in 1996.

The total seed harvest in the Swedish orchards is at least 570 kg out of which the hybrid orchard in Maglehem has produced 380 kg. However, the amount of collected seed could have been larger since there are years when no seed was harvested beacuse of lack of commercial interest. Frost problem during the sensitive period of flowering have of course reduced the seed production as well.

Breeding activities

The Swedish larch breeding started in the beginning of the 1940's by the Institute for Forest Improvement. Since results from field trials showed that the L. eurolepis hybrids were superior to the parent species Swedish breeding efforts have been concentrated on improving these hybrids. In northern Sweden L. sibirica x L. decidua seems to be preferable reagarding yield and survival. The activities were rather intensive until the 1960's. However, most of the established field trials consist of rather few families and were designed for comparisons with Norway spruce. Progeny tests have only been carried out for the clones in 2 of the orchards, which means that the genetic traits for most of the orchard clones are unknown.

The recent 20 years very few activities has been carried out due to the poor interest. However, we will now start up a new larch breeding programme aiming at producing better material to hybrid as well as to pure larch seed orchards.


Active orchards
Closed down orchard:
Orchards possible to
reactivate

Active seed orchards in Sweden

Number and name	Species	Lat, Long, Altitude	Year of establ.	Area, ha	Material	Harvest
51. Maglehem	L. kaempferi x L. decidua	55° 46'N, 14° 10' E 20 m above sea level	1957-58	3.5	1 L. kaempferi clone and 9 L. decidua clones. Progeny tested.	380 kg during 1968-1991
92. Klev	L. decidua x L. kaempferi	55° 46'N, 14° 10' E 45 m above sea level	1962	3.0	Originally 20 L. kaempferi clones. Later on one L. decidua clone was included	Only small quantaties of hybrid seed
741. Hjälmshult	L. kaempferi x L. decidua	56° 08' N, 12° 41 ' E 25 m above sea level	1962	1.1	Originally 30 L. decidua clones. One L.kaempferi clone will be included in 1996.	None hybrid seeds
73. Långtora	L. kaempferi x L. sibirica	59° 43' N, 17° 02' E 50 m above sea level	1962	2.0	1 L.kaempferi clone and 10 L.sibirica clones.	20 kg during 1977-1986
14. Östteg	L. sibirica	63° 48' N 20° 16' E 5 m above sea level	1956-59	4.0	30 clones	45 kg during 1985-1989
413. Domsjöänget	L. sibirica	63° 12' N 18° 46' E 15 m above sea level	1953-66	2.0	22 clones	95 kg during 1961-1991
124. Dammsjön	L. sibirica	60° 28' N, 16° 23' E 135 m above sea level	1963	4.2	15 clones	?

New seed orchards in the 1990's.

Number and name	Species	Lat, Long, Altitude	Year of establ.	Area, ha	Material
Trolleholm	L. kaempferi x L. decidua	55° 55' N 13° 21' E 95 m above sea level	1992	2.0	Elite seed orchard. 1 L. kaempferi clone and 7 L. decidua clones.
?	L. decidua x L. kaempferi	?	1996	2.0	Elite seed orchard. 1 L. kaempferi clone and 6 L. decidua clones.

GEOGRAPHIC VARIATION IN MODULUS OF ELASTICITY AND HEARTWOOD RATIO AMONG 24 PROVENANCES OF JAPANESE LARCH

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SUMMARY

Japanese larch (*Larix kaempferi* (lamb.) Carr. syn. *Larix leptolepis* Gord.) is one of the most important economic species of Japan. The species is expensively used for reforestation outside its natural range in northern Japan, Europe, USA and Canada since it is recognized as rapid-growing and disease-resistant.

The international provenance trial with Japanese larch was organized by Dr. Langner and 25 seed sources were selected by Japanese Government Forest Experiment Station (present name is Forestry and Forest Products Research Institution) in 1956. Forty-four parallel trials were established in 9 European countries, USA, Canada, New Zealand and Japan.

In this study, geographic variations in modulus of elasticity (MOE) and heartwood ratio of Japanese larch from 24 natural forests (24 provenances) were studied at three provenance trials established in the area of its natural distribution. The objectives were to collect the genetic information on the geographic variation pattern of the two wood properties.

Analyses of variance for the two properties were performed for individual trials. The between-provenance differences in MOE were significant at the 1 percent level for each trial. Two provenances, Sangoome and Kobushidake sources performed excellently in every trial and were recommended for the seed soruces to establish man-made forest for timber production. In the other hand, there were no significant differences in heartwood ratio among the 24 provenances. The between-tree range in this property was very large, from 48 to 81 percent.

Key words: Japanese larch, provenance, modulus of elasticity, heartwood ratio

HYBRID BREEDING IN THE GENUS *LARIX* - RESULTS AND TRANSFER INTO FORESTRY PRACTICE

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Abstract

Since the end of the 60s, the forests in the mountainous regions of Saxony were damaged more and more by the effects of air pollution. The increasing damages to forests led to intensive efforts in Larch breeding in order to supply forestry with reproductive material which is able to cope with the difficult climatical conditions of these regions as well as with air pollution. Based on early results of intra- and interspecific crossings within and between the species ***Larix decidua*** MILL. and ***Larix kaempferi*** (LAM.) CARR. started in 1956, about 100 clones were tested on their combination ability untill today. Performance, quality and resistance characteristics were observed in 24 field experiments. Additionally, experiments on the SO_2-resistance of the hybrids were done in the laboratory.

According to the results of the field and the laboratory testing, seven hybrid combinations showed excellent growth characteristics combined with SO_2-resistance in the field and the laboratory. The quality ranged between average and excellence. All combinations had only little loss during the test period of 30 years and showed no susceptibility to breaking caused by snow.

For the procurement of reproductive material of these combinations, different approaches are used. In the long term, the material will be produced in seed orchards which were established between 1985 and 1989. The proportion of hybrids already produced is monitored regulary by isozyme analysis. In the short term, the tested combinations are reproduced by repeated crossings. According to the demand, the material is supplied as seedlings or as cuttings of seedlings using vegetative propagation.

In future, breeding research will concentrate on the broadening of the genetic base by the evaluation of more combinations suitable for planting in the mountainous regions. On the other hand, the use of hybrids in a natural orientated silviculture is often restricted by the not predictable characteristics of the natural regeneration of Larch hybrid stands. In this context, investigations are necessary on the inheritance of traits in the second generation under special consideration of spontaneous hybridization.

Provenance research on *Larix* in Sweden -

Summary from a forest excursion August 1-4, 1995.

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Introduction

Larch is an important and partly dominant component of the boreal and alpine forests throughout the world. However, after the last glaciation larch has not returned through natural migration to Scandinavia. In Sweden larch was introduced by man in the 1760s.

For the last 200 years the interest among Swedish foresters for larch as a forest crop tree has been going up and down several times. The first introductions were larch seedlings of European larch (*Larix decidua* Mill.) from Scotland. The origin of the larch introduced into to Scotland was probably Tirolia. Later on larch was also introduced to Sweden from the Alpine region and in the 19th century Siberian larch (*Larix sukaczewii* Dyl.) was introduced from Russia, mainly from the Archangelsk region.

In the 1950s the interest for larch was growing in many European countries. Several international larch provenance series were established. Professor Milan Simak was active at the Swedish Forest Research Institute and started an extensive programme for larch provenance research. During the period 1968-1974 Simak established at least 20 different provenance trials of 7 different larch species. Many of these were parts of international provenance series.

During our excursion we will visit and discuss 3 different series of provenance trials: The Japanese larch series (*Larix kaempferi* Carr.) established 1960-61, the European larch series (*Larix decidua* Mill.) established 1960 and 1968 and the series of tamarack larch (*Larix laricina* (DuRoi) K. Koch).

EXCURSION PROGRAMME

IUFRO-S2.02-07 Working Party on Larch Provenances and Breeding
Billingehus and Siljansfors July 31 - August 4, 1995

August 1: Remningstorp

1a Närsäter: Provenance trial of *Larix kaempferi*, established in 1960.

1b Närsäter: Provenance trial of *Larix decidua*, established in 1961.

1c Storänget: Provenance trial of *Larix laricina*, established in 1974.

1d Jonstorpsmossen: Provenance trial of *Larix laricina*, established in 1974.

August 2: Visingsö, Omberg, Aspanäs, Zinkgruvan

2. Visingsö: Trials of *Larix decidua, L. sukaczewii* and *L. kaempferi* established in the 19th century.

3. Omberg: Trials of *Larix decidua, L. sukaczewii* and *L. kaempferi* established in the 19th century.

4. Aspanäs: Hybrid larch field trial established in 1961.

5. Zinkgruvan: Stand establishment of larch through direct seeding.

August 3: Siljansfors Forest Experimental Station

6. Leksberget: Provenance trial of *Larix decidua,* established in 1968.

   Siljansfors Forest Museum.

August 4: Bogesund Forest Experimental Station

7. Röskär: Provenance trial of *Larix kaempferi* established in 1961.

Japanese larch (*Larix kaempferi* Carr.)

Excursion points 1a and 7

These experimental sites of Japanese larch are parts of the international series which was established in several countries of the world on initiative of Dr Langner and the Japanese Forest Experiment Station in 1956. The two sites visited during this excursion, 1855 Remningstorp and 1850 Röskär, were established in 1960 and 1961 respectively. In addition to these two, similar experimental areas were established in two more sites 1851 Maglehem and 1853 Tönnersjöheden, both in 1961.

The origins of the Japanese seed sources and the localities of the experimental sites in Swden are recorded in table 1 and figure 1.

Table 1. Localities of the seed sources of Japanese larch in the 4 experimental sites in Sweden.

Provenance		Area	Community	Lat N	Long E	Altitude, m above see
1	VI	Mt Fuji	Narusawa	35°26'	138°41'	1320
2	VI	Mt Fuji	Narusawa	35°24'	138°43'	1760
3	VI	Mt Fuji	Narusawa	35°23'	138°43'	2420
4	V	Mt Azuza	Kawakami	35°57'	138°43'	1500
5	V	Toyosatu	Kitamaki	36°02'	138°24'	1780
6	V	Ohira	Minamimaki	36°01'	138°26'	1750
7	V	Tateshina	Tateshina	36°06'	138°17'	1600
8	V	Kitayama	Yoshino	36°02'	138°20'	1700
9	V	Nishidake	Fujimi	35°56'	138°18'	1450
10	V	Nishidake	Fujimi	35°57'	138°20'	1750
11	IV	Kurokochi	Miwa	35°45'	138°12'	1500
12	IV	Hontaniyama	Kami	35°27'	138°06'	2000
13	III	Akanuma	Nikko	36°47'	139°27'	1360
14	III	Okunikko	Nikko	36°47'	139°27'	1490
15	III	Yashubara	Nikko	36°47'	139°32'	1700
16	II	Kumashiroyama	Tsumakoi	36°38'	138°30'	1750
17	II	Mizunoto	Tsumakoi	36°24'	139°29'	1900
18	II	Nagakurayama	Karuizawa	36°23'	138°29'	1420
19	II	Oiwake	Karuizawa	36°23'	138°34'	1700
20	I	Kamikochi	Azumi	36°14'	137°38'	1620
21	I	Rengeyama	Itoigawa	36°48'	137°48'	2180
22	I	Takasegawa	Omachi	36°26'	137°41'	1380
23	IV	Kurokwa	Komagani	35°48'	137°52'	1800
24	I	Shikanose	Mitake	35°54'	137°34'	1380
25	I	Kanagi	Nakawa	36°04'	137°43'	1920
26		Skåne: fröblandning från två bestånd i Knutstorp och Vasatorp				
Försöksytor						
1850 Röskär				59°24'	18°11'	35
1851 Maglehem				55°45'	14°02'	100
1853 Tönnersjöheden				56°41'	13°01'	100
1855 Remningstorp				58°28'	13°33'	130

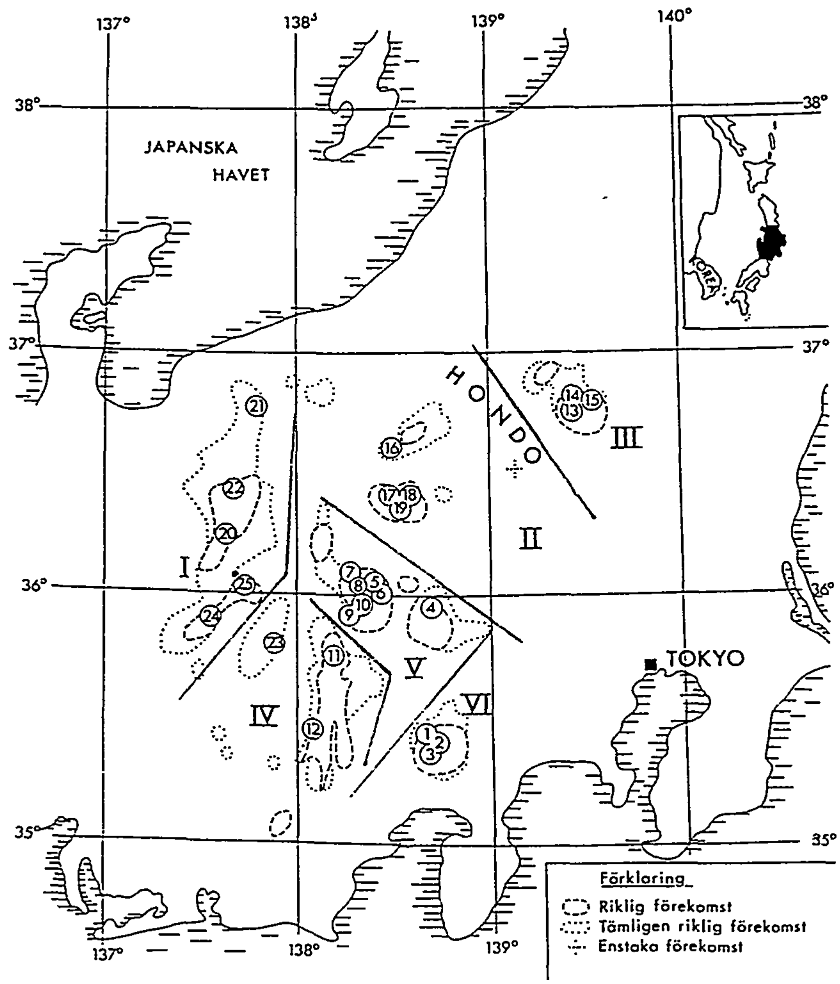

Figure 1. The origins of the provenances in the Japanese main island, Honshu.

The experiments have been measured and estimated for rate of survival and tree height. At the last revision the stem straightness of experiment 1855 was rated as well according to the following scale: 0=Straight stem, 1=Small crook in the upper part of the tree, 2=Small stem sweep, 3=Big stem sweep (figure 3).

Table 2. Survival. Number of trees alive at the time of the first thinning in % of those established.

Provenance	1850 Röskär	1851 Maglehem	1853 Tönnersjöheden	1855 Remningstorp
1	40	87	21	9
2	55	91	30	21
3	--	--	--	37
4	23	76	26	35
5	48	81	57	61
6	53	87	25	61
7	62	83	37	73
8	53	81	61	72
9	--	79	--	52
10	63	88	--	33
11	48	83	--	21
12	--	--	30	23
13	92	89	86	86
14	58	98	59	79
15	70	88	63	83
16	78	89	89	83
17	--	91	77	96
18	63	89	52	38
19	68	61	34	42
20	--	--	--	58
21	--	--	--	91
22	73	92	53	53
23	45	--	51	80
24	81	83	64	77
25	79	76	61	72
26	46	--	72	--

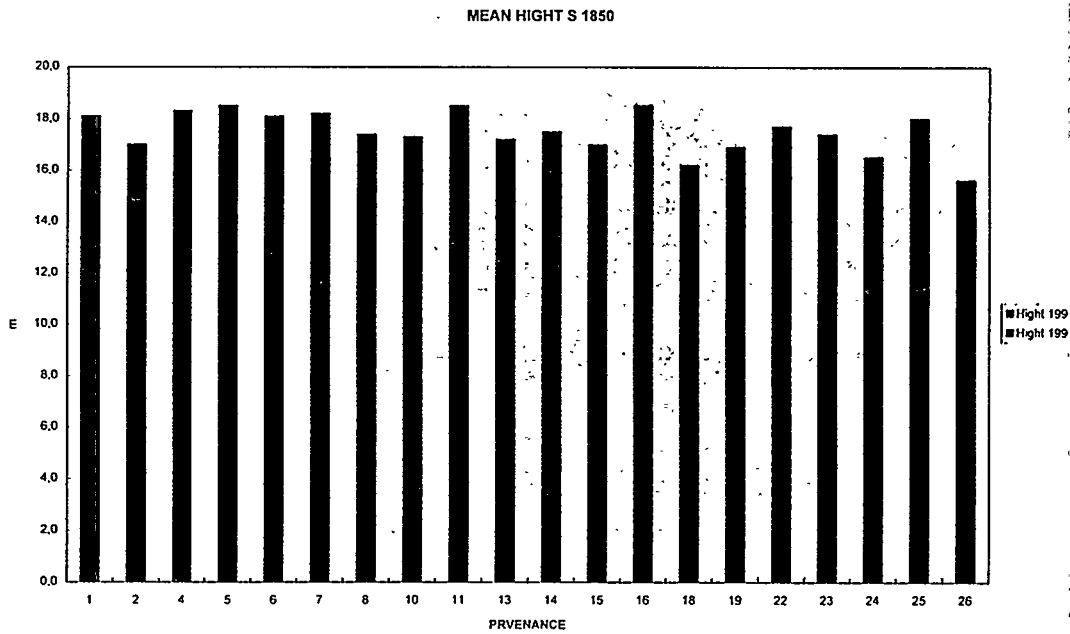

Figure 2a. Experimental plot 1850 *Larix kaempferi*, Röskär. Mean tree height of provenances 30 and 34 years after planting.

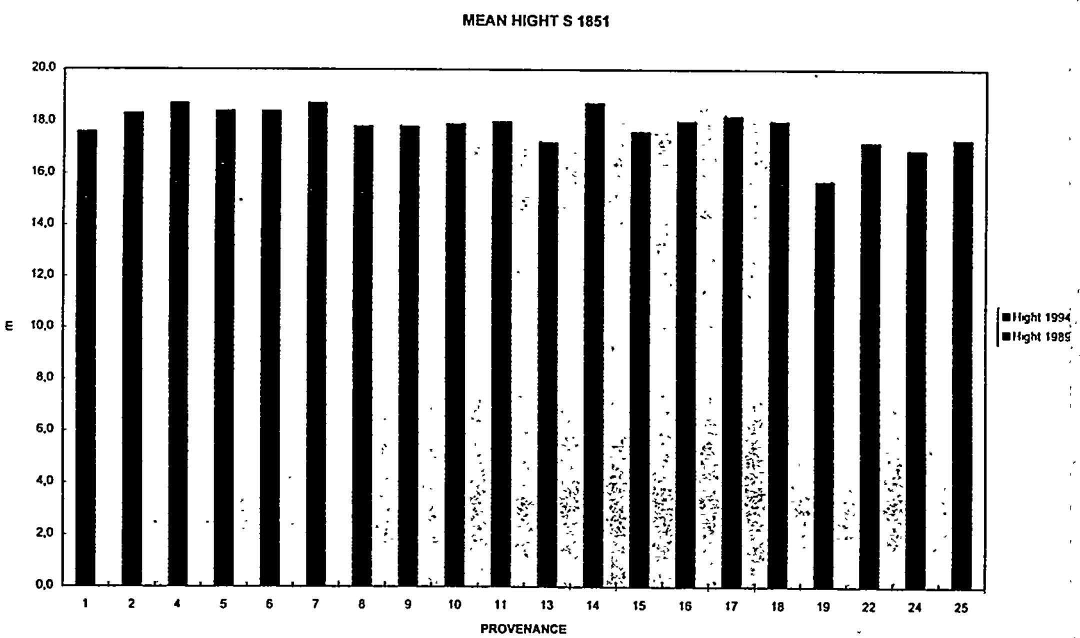

Figure 2b. Experimental plot 1851 *Larix kaempferi*, Maglehem. Mean tree height of provenances 30 and 34 years after planting.

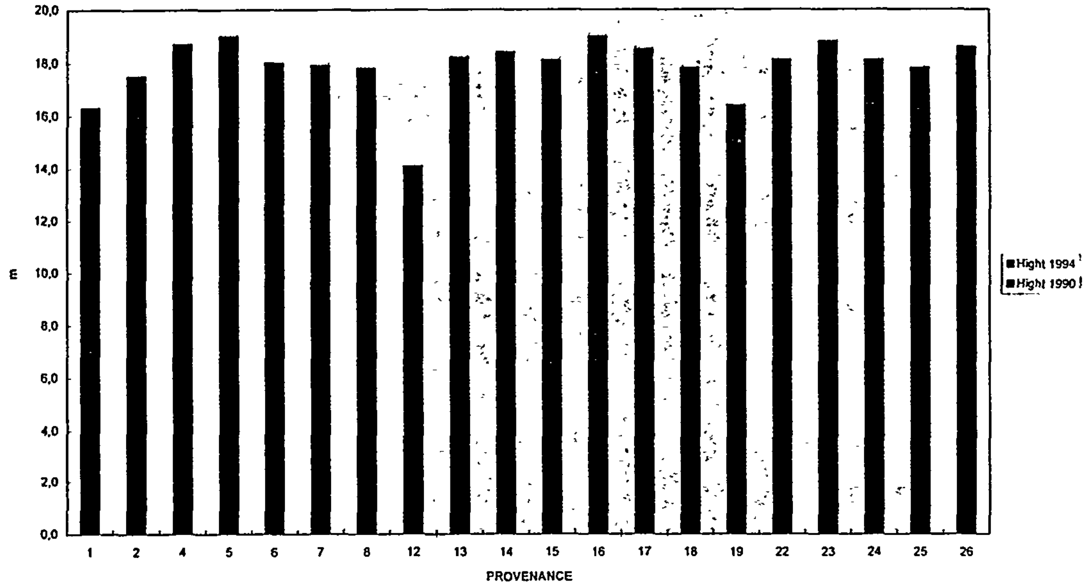

Figure 2c. Experimental plot 1853 *Larix kaempferi*, Tönnersjöheden. Mean tree height of provenances 30 and 34 years after planting.

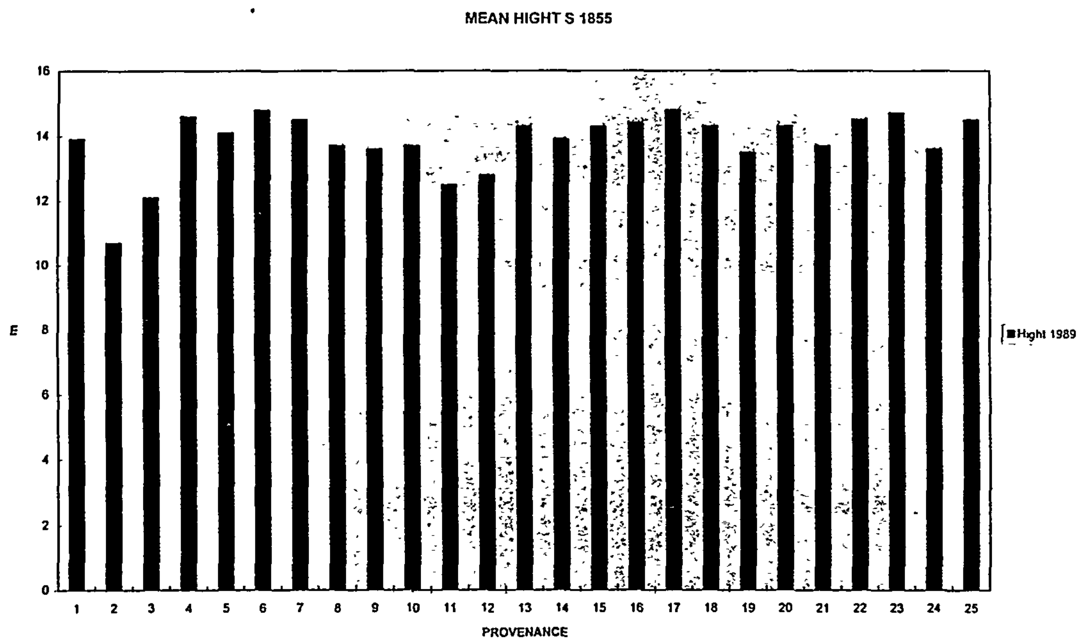

Figure 2d. Experimental plot 1855 *Larix kaempferi*, Remningstorp. Mean tree height of provenances 29 years after planting.

The mean tree height of provenances at the two last revisions are given in figures 2a-2d. The stem straightness estimated at the last revision in 1855 Remningstorp is given in figure 3.

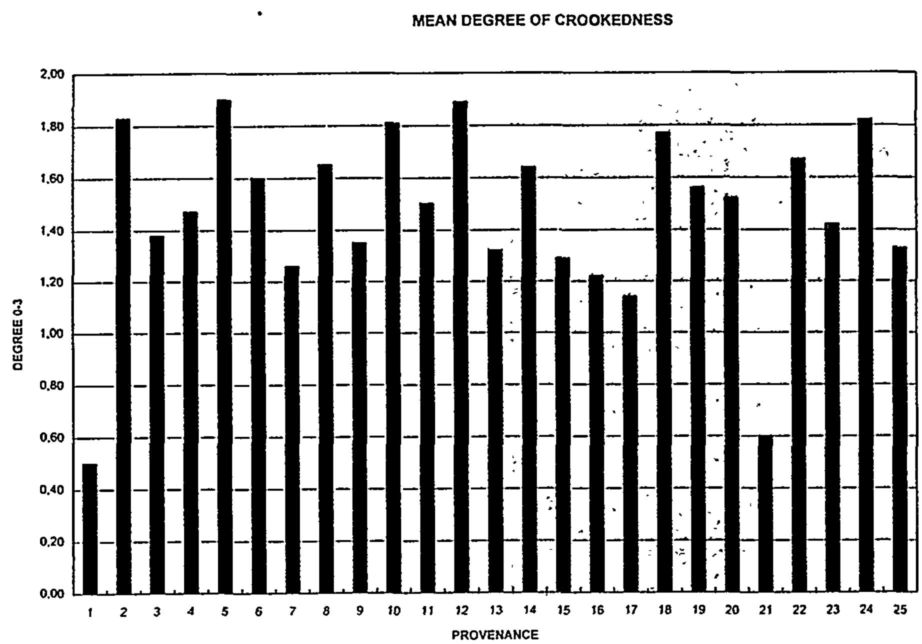

Figure 3. Mean stem straightness of provenances in 1855 Remningstorp.

Main findings

Provenances from the most northern seed sources in the material have usually a better survival, growth rate and stem form than have the southern and western seed sources.

An interaction between the stem straightness of provenances and site seems to be possible.

At the age of 33 years the most productive provenances of Japanese larch may have a mean height of 19-20 m in southern Sweden and a total production of more than 400 m^3 per hectare.

A high frequency of but rot (*Heterobasidion annosum*) was found in one of the experimental sites (1853 Tönnersjöheden).

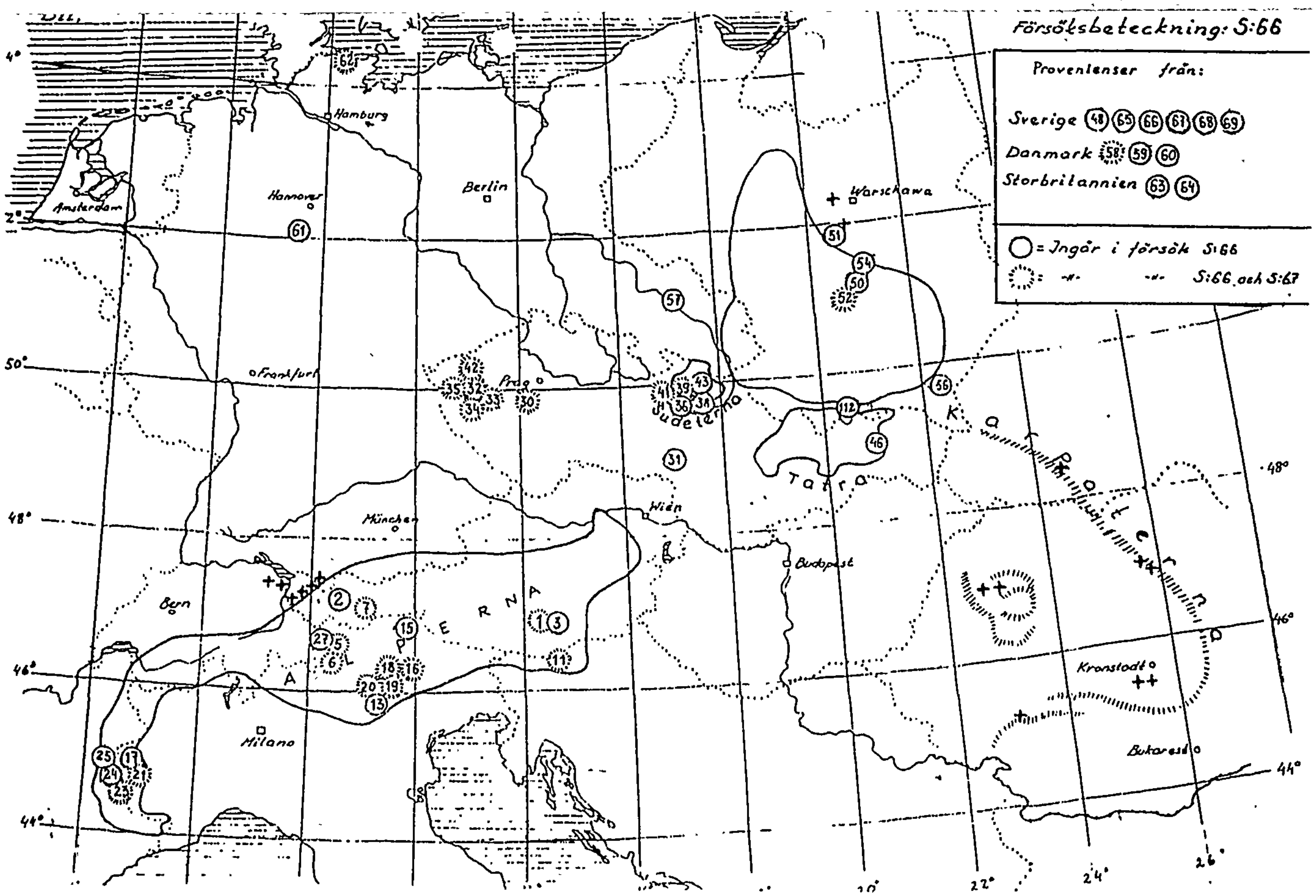

Figure 4. Origins of provenances used in experiments of *Larix deciuda* in Sweden

European larch (*Larix decidua* Mill.)

Excursion points 1b and 6

The two experimental sites visited during the excursion are 1866 Remningstorp and 1891 Siljansfors. These two experimental plots were established 1961 and 1968, respectively. Local conditions for the experimental sites are given in table 3.

Table 3. Locality and site conditions for the experimental sites 1866 and 1891.

No	Lat. N	Long. E	Altitude	Exposition	Soil
1866	58°28'	13°33'	130	rolling	till
1891	60°55'	14°23'	400	W slope	till

The material of these trials are to a great extent identical to the seed material used in the international provenance trials of European larch established in the 1960s (Schober 1977). The origins of the material in these two and three other plots are given in table 4 and figure 4.

Mean tree height of provenances and stem straightness were recorded in the two experimental plots (figures 5 and 6).

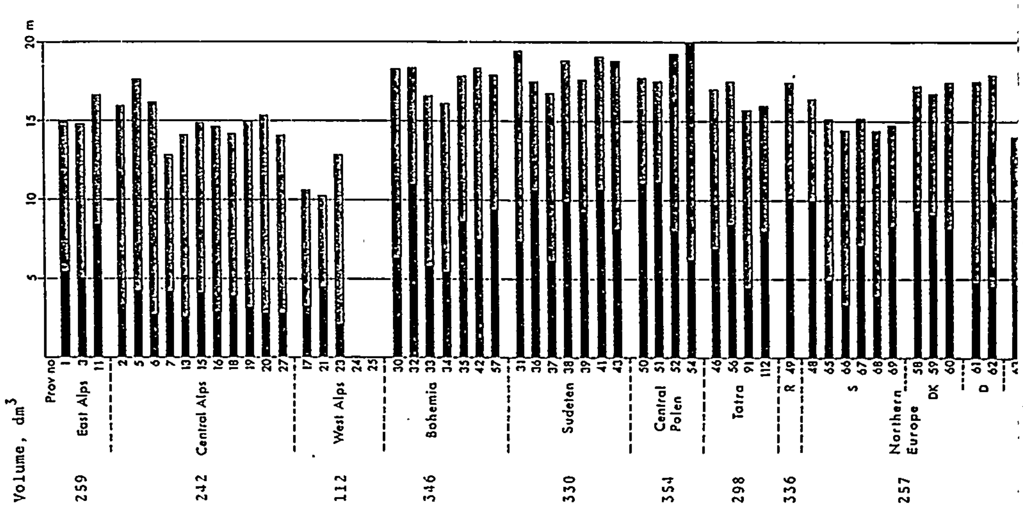

Figure 5. Mean tree height of provenances 29 years after planting in experiment 1866. The lower part of the columns indicate survival of seedlings (living trees at the first thinning in % of established seedlings x mean tree height).

Table 4. Origins of provenances of *Larix decidua* used in experiments nos 1865, 1866, 1886, 1891 and 240. X=included in the experiment.

No	Locality	Alt. m	Country	1865	1866	1886	1891	240
1	St Lamprecht	1100-1400	A		x			
2	Schönweiss	1100	A		x		x	
3	St Lamprecht	1100-1400	A		x			
5	Stilfser Tal	800-1400	A		x	x		x
6	Stilfser Joch	1000-1400	A		x			
7	Längenfeld	1300-1700	A		x			x
8	Semmering	1200	A					x
11	Urslja Gora	1200	YU		x			
13	Vigolo Vattaro	700	I		x			
15	Ahrntal	1100	I		x			
16	Val di Fiemme	1300-1300	I		x			
17	Pragelato	1700-1800	I		x	x		
18	Tenna	600	I		x			x
19	Peregrine	1400	I		x			x
20	Cavedine	600-700	I		x			x
21	Pragelato	1900	I		x			
23	Aiguille	1450	F		x			
24	St Pierre	1700	F		x		x	x
25	St Vincent	1850	F	x	x			
27	Münstertal	1250-1500	CH		x			
30	Dobris	500	CS		x			
31	Brno		CS		x			
32	Habruvka		CS		x			
33	C. Porici	420	CS		x			x
34	Slavetin	590	CS		x			x
35	Habartice	550	CS		x			x
36	Broumov	500	CS		x			
37	Karlovice	600	PL		x			
38	Jaromerice	440	CS		x			
39	Dubicko	450-550	CS		x			
41	Bruntal		CS		x			
42	Chejlava		CS		x			
43	Karlovice	550-700	CS		x			x
44	Krnov	650	CS	x		x	x	x
46	Sabinov	650	CS		x			
47	Cierny Vah	1100	CS	x				
48	Skabersjö		S		x			
49	Rumänien	1100	R	x	x			
50	Skarzysko	380	PL		x			
51	Grojec	180	PL		x			
52	Blizyn	330	PL		x			
54	Radom		PL		x			
55	Blizyn	350-370	PL	x		x		
56	Przemysl	200-500	PL		x			
57	Wroclaw	300-600	PL		x			
58	Nödebo		DK		x	x		x

Table 4, continued

No	Locality	Alt. m	Country	1865	1866	1886	1891	240
59	Ganlöse	50	DK		x			
60	Jaegersborg	30	DK		x			
61	Schlitz		D	x	x	x		
62	Neumünster		D		x			
63	Bauffshire	220	GB		x			
64	Dunira osv.		GB		x			
65	Edsgatan		S		x			
66	Nyköping		S		x			
67	Mölndal		S		x			
68	Skottorp		S		x			
69	Lilla Svältan		S		x			
71	Savognin	1300	CH					x
75	Trins	1500-1700	CH	x				
77	Domat-Ems	1500-1800	CH					
81	Chamonix	1210	F					x
82	Smokovec	1150-1250	CS				x	x
83	Stare Hory	850	CS					x
84	Ipoltica	780-830	CS			x	x	x
85	Brezovicka	820-840	CS			x	x	x
86	L. Teplicka	1350-1420	CS					x
87	Strbske Pleso	1360-1380	CS			x		x
89	Chemelienec	750	CS					x
91	Brezovicka	500-650	CS		x			
101	Lissjö		S	x				
112	Pieniny	550	PL		x			
113	Mezahlje		YU	x				
115	Krvavec		YU		x	x		x
121	Murau	500	A					x
130	Cervena Skala	500	CS				x	x
132	Vigo Cavedine	1000	I					x
Total number of provenances				9	55	10	7	26

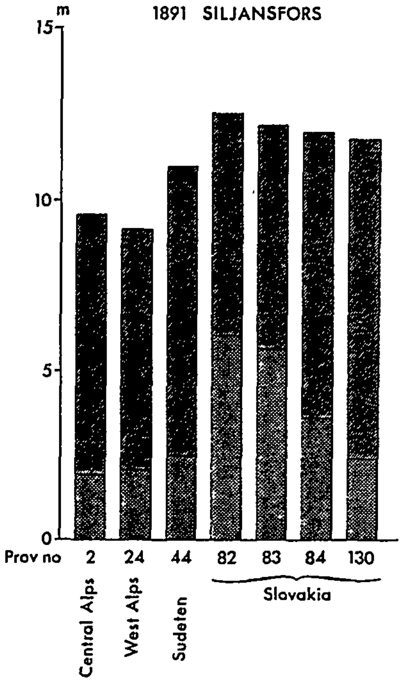

Figure 6. Mean tree height of provenances 22 years after planting in experiment 1891. The lower part of the columns indicate survival of seedlings (living trees at the first thinning in % of established seedlings x mean tree height).

Main findings

Provenances of European larch from eastern Europe, i e Poland, the Tatra mountains, Slovakia, Bohemia, are superior to provenances from the Alp-region in terms of survival and productivity.

Some of the provenances from the Sudet-area (northern Bohemia) do not have straight stems.

The most productive provenances will reach a mean tree height of 20 m in 29 years in Remningstorp (Lat N 58°28', alt 130 m) and 14 m in 22 years in Siljanfors (Lat N 60°55', Alt 400 m).

Tamarack (*Larix laricina* DuRoi (K Koch))

Excursion points 1c and 1d)

The two experiments visited are both localized in Remnigstorp: 1907 Storänget and 1904 Jonstorpsmossen. These experiments were established in 1974.

The seed origins are mainly eastern Canada. A few provenances are from western Canada and 1 provenance originate from Alaska (figure 7, table 5). Norway spruce (P A), Scots pine (P S) and pubescent birch (B P), all of local origins, are also included in these experiments.

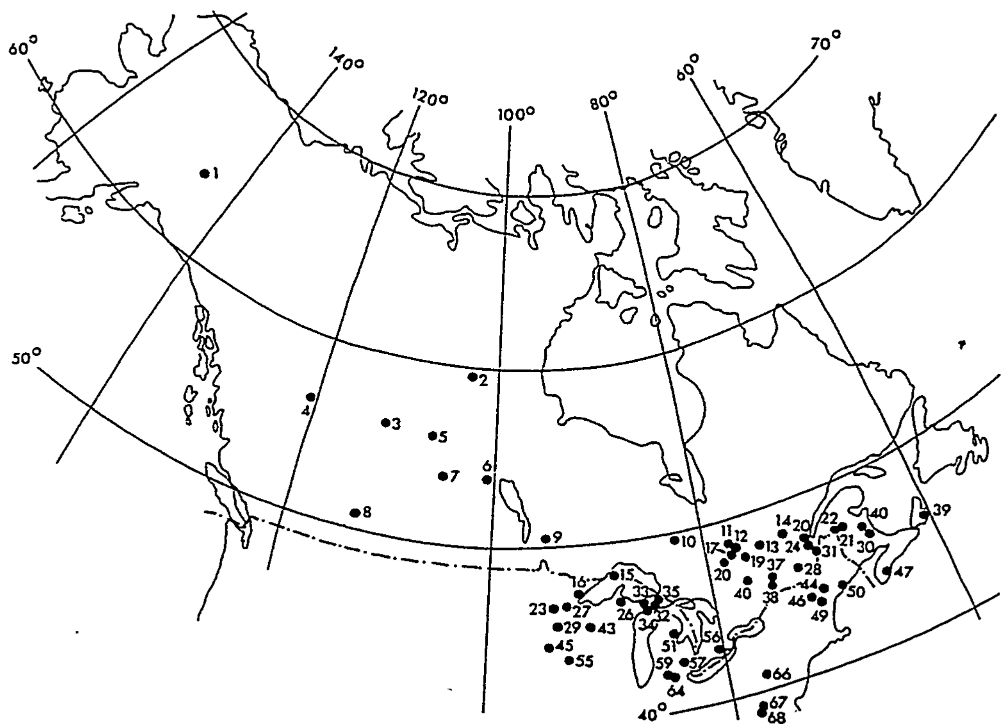

Figure 7. Origins of provenances used in experiments 1904 Jonstorpsmossen and 1907 Storänget, both in Remningstorp.

Table 5. Origins of seed sources of experiments 1904 Jonstorpsmossen and 1907 Storänget.

P No	State	County	Lat N	Long W	Alt m	
1	Alaska	Tanana Ri	65 00	147 30	150	
2	N W T	----	58 58	111 40	229	
3	Alberta	Waterways	56 39	111 14	335	
4	B C	Fort St John	56 38	120 35	732	
5	Saskatche	Buffalo Norrows	56 05	108 55	427	
6	Manitoba	The Pas	53 55	101 15	260	
7	Saskatche	Meadow Lake	53 50	108 40	640	
8	Alberta	----	51 00	101 00	740	
9	Manitoba	Winnipeg	50 05	95 25	229	
10	Ontario	Gurney Twp	49 30	82 14	213	
11	Quebec	Chagel	48 55	79 03	290	
12	Quebec	Preissac	40 30	78 15	--	
13	Quebec	Roberval	48 26	72 16	336	
14	Quebec	Roberval	48 26	72 16	--	
15	Michigan	Isle Royale	48 05	88 42	186	**
16	Minnesota	St Louis	48 02	91 37	397	**
17	Quebec	Preissac	48 01	78 17	321	
18	Quebec	Guerin	47 45	79 20	--	
19	Quebec	Lake Lortie	47 40	74 15	--	
20	Quebec	Seign Malbaie	47 40	70 20	244	
21	Quebec	Cabano	47 39	68 57		
22	Quebec	Cabano	47 39	68 57	244	
23	Minnesota	Itasca	47 31	94 05	396	
24	Quebec	La Malbaie	47 20	70 20	--	
26	Michigan	Houghton	47 01	88 25	201	
27	Minnesota	St Louis	47 00	93 00	387	*
28	Quebec	Radnor	46 45	72 50	--	
29	Minnesota	Carlton	46 42	92 31	335	**
30	Nova Scoti	Chignecto	46 35	64 25	80	
31	Quebec	Langevin	46 21	70 22	--	
32	Michigan	Alger	46 21	86 20	244	**
33	Michigan	Alger	46 20	86 20	244	**
34	Michigan	Alger	46 20	86 20	244	
35	Michigan	Chippewa	46 19	84 14	183	*
36	Michigan	Cogebic	46 15	89 10	488	
37	Quebec	Berthier Parta	46 15	73 15	--	
38	Quebec	Lake Chertsey	46 11	73 52	--	
39	Nova Scoti	Beddec	46 07	59 45	30	
40	New Brunsw	Acadia Forest	46 00	66 20	98	
41	Ontario	--	46 00	77 26	146	**
43	Wisconsin	Oneida	45 46	89 12	366	
44	Maine	Somerset	45 38	70 16	362	
45	Minnesota	Anoka	45 10	93 05	244	

Table 5, continued

P No	State	County	Lat N	Long W	Alt m	
46	Vermont	Franklin	44 57	73 05	70	
47	Nova Scoti	Annapolis	44 48	65 03	229	
49	Vermont	Lamoille	44 30	72 37	229	
50	Maine	Mt Desart Is	44 30	68 00	30	**
51	Michigan	Wexford	44 15	85 31	393	
55	Wisconsin	Lacrosse	43 51	91 08	206	
56	Ontario	Oxford	43 13	80 35	297	
57	Michigan	Livingstone	42 30	83 30	274	**
59	Michigan	Livingstone	42 29	84 20	244	**
64	Michigan	Kalamazoo	42 23	85 22	256	**
66	Pennsylv	Lackawanna	41 15	75 39	598	**
67	Maryland	Garrett	39 42	78 56	820	**
68	Maryland	Garrett	39 42	78 56	820	**
69	B C	--	--	--	--	

** Not planted in 1907 Storänget
* " " 1904 Jonstorpsmossen

Both experiments are growing on organogenic soils. However, 1907 Storänget on a fertile black peat soil with mineral influence from the surrounding area and 1904 Jonstorpsmossen on a poor Sphagnum peat bog.

The mean tree height of provenances, rate of survival and stem form are indicated on the figures 8 and 9.

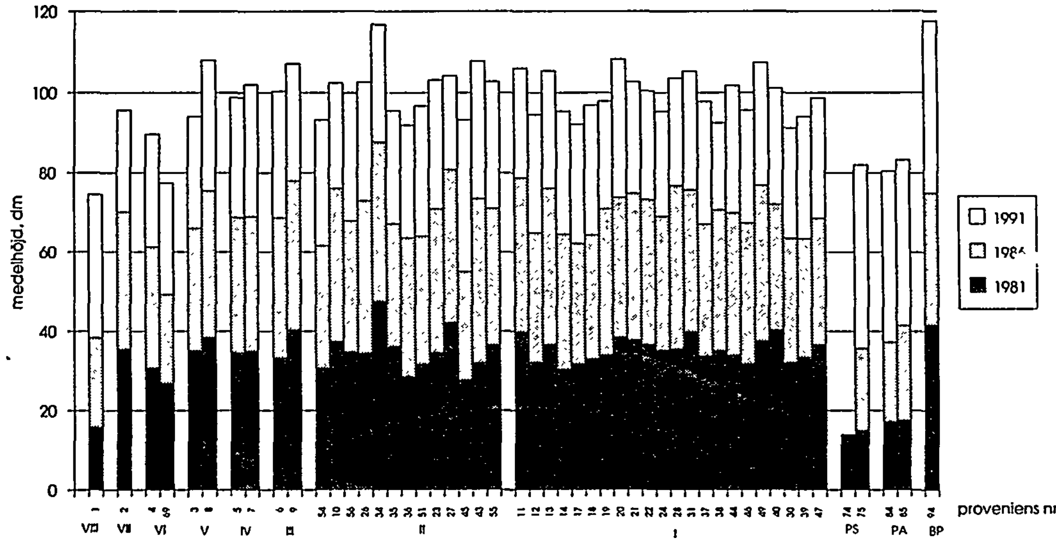

Figure 8. The mean tree height of provenances, experiment 1907 Storänget.

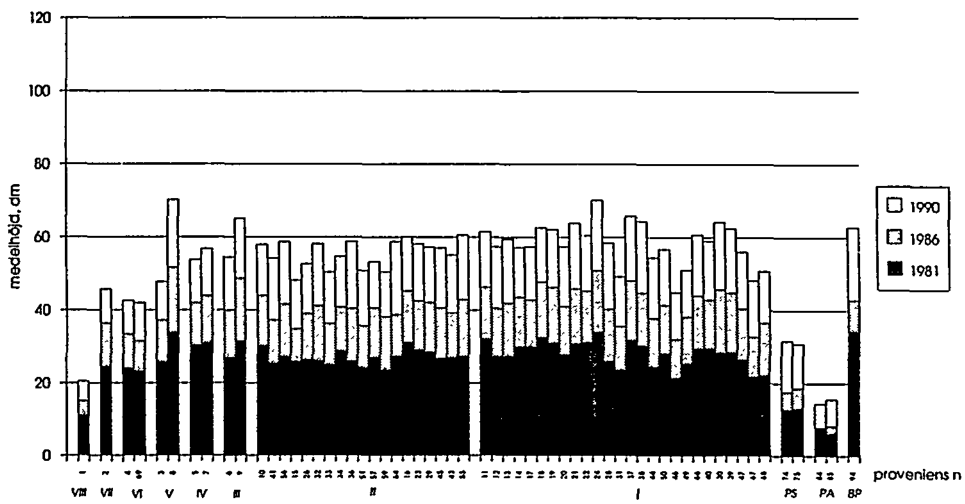

Figure 9. The mean tree height of provenances, experiment 1904 Jonstorpsmossen.

In addition to these two experiments the Department of Silviculture has records of 6 other provenance experimental sites of tamarack, where some of the seed sources used are identical to those of experiments 1904 and 1907.

Main findings

Canadian seed sources of tamarack should not be transferred into Sweden more than 6-7 degrees of latitude north.

Seed sources of tamarack from western North America should be used in northern Sweden and seed sources from high elevation for cultures in sites of cold local climate.

The level of productivity is to a great extent influenced by the local soil conditions.

The stability to wind is a serious problem of tamarack in fast growing, pure cultures.

On rich peat soils in southern Sweden, tamarack of suitable provenance can produce a stem volume of 90-100 m^3 per hectares and a mean tree height of 12 m during the first 17 years after planting.

. **Mellberg, I. & Näslund, B-Å.:** Barrotsplantors tillväxt och överlevnad fram till röjningstidpunkt. - Resultat från en försöksserie med skilda plantsorter. (*Growth and survival for bare-root seedlings until the time of cleaning. - Results from experimental series with different types of seedlings*).

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. **Simak, M. & Bergsten, B.:** Databas över skogsfrölitteratur publicerad i Sverige fram till 1975. (*Data base on forest seed literature published in Sweden up to 1975*).

. **Pehap, A., Henriksson, G. & Sahlén, K.:** Respiration of germinating spruce seeds: Further investigations and measurements with the Warburg direct method.

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5. **Jeansson, E., Bergman, F., Elfving, B., Falck, J. & Lundqvist, L.:** Natural regeneration of pine and spruce. - Proposal for a research program. Faculty of Forestry. Swedish University of Agricultural Sciences.

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6. **Örlander, G., Hallsby, G. & Sundkvist, H.:** Överlevnad och tillväxt hos tall (*Pinus sylvestris*) och gran (*Picea abies*) samt näringsförhållanden 23 år efter plantering på helplöjd resp bränd tallhedsmark.

7. **Gemmel, P. & Nilsson, U.:** Competition between originally planted and beeted seedlings in stands of Norway spruce and Scots pine.

8. **Lundqvist, L.:** Blädningsytan i Gammels-torp - en demonstrationsyta skött med stamvis blädning. (*The selection plot in Gammelstorp - a permanent plot with single tree selection*).

9. **Martinsson, O.:** Den ryska lärkens höjdutveckling och volymproduktion i norra Sverige. (*Height growth and volume production of Russian larch (Larix sukaczewii Dyl.) in northern Sweden*).

30. **Fries, C.:** Utveckling hos beståndsföryngrad gran och kompletteringsplanterade granar och tallar i ett kärvt klimatläge. (*Developement of advance growth of Norway spruce and supplementary planted spruce and Scots pine in a harsch climate*).

31. **Sugg, A.:** Seedling establishment results from a site preparation study in southern Sweden: The first four years survival and growht of Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.)

1991

32. **Hånell, B.:** Förnyelse av gransumpskog på bördiga torvmarker genom naturlig föryngring under högskärm. (*Shelterwood regeneration of spruce forests on productive peatlands*).

33. **Örlander, G., Gemmel, P. & Wilhelmsson, C.:** Markberedningsmetodens, planteringsdjupets och planteringspunktens betydelse för plantors etablering i ett område med låg humiditet i södra Sverige. (*Effects of scarification, planting depth and planting spot on seedling establishment in a low humidity area in southern Sweden*).

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34. **Hånell, B.:** Skogsförnyelse på högproduktiva torvmarker - plantering av gran på kalhygge och under skärmträd. (*Forest renewal on productive peatlands: Planting of Norway spruce on clearcuts and in shelterwoods)*.

35. **Silvicultural alternatives.** Proceedings from an internordic workshop June 22-25 1992. Editor: Mats Hagner.

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36. **Andersson, B.:** Lövträdens inverkan på små tallars (Pinus sylvestris) överlevnad, höjd och dimeter. (*The influence of broad-leaved trees on survival, height and diameter of small Scots pine (Pinus sylvestris L.) trees*).

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37. **Valinger, E. & Lundqvist, L.:** Reducing wind and snow induces damage in forestry.

1995

38. **Putenikhin, V.P. & Martinsson, O.** Present distribution of *Larix sukaczewii* Dyl. in Russia

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